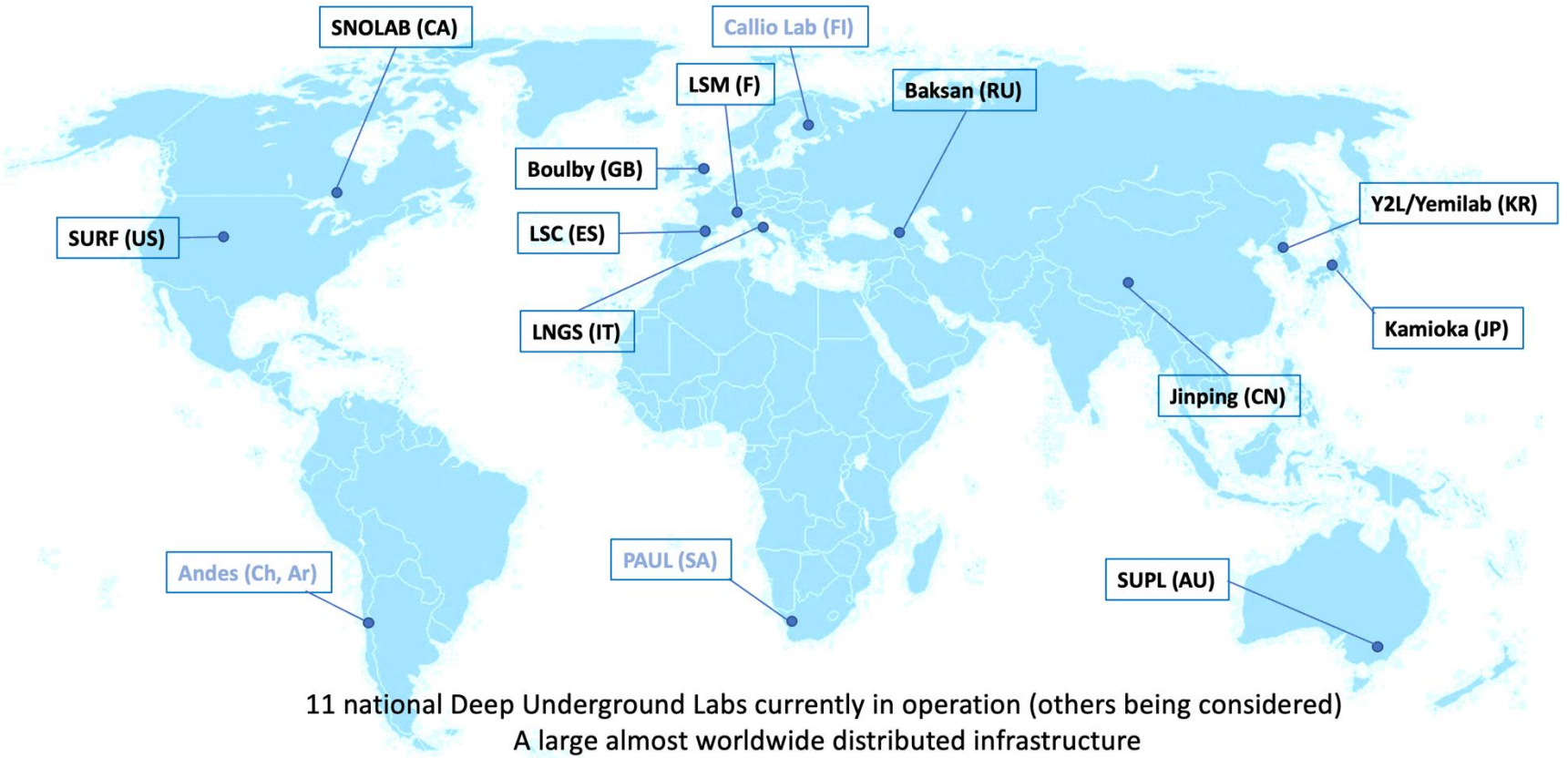
Overview of World Deep Underground Science Facilities



11 national Deep Underground Labs currently in operation (others being considered)
A large almost worldwide distributed infrastructure

Sean Paling
STFC Boulby Underground Laboratory

Science and Technology Facilities Council
Boulby Underground Laboratory

Why go underground?

Deep Underground Science Themes

Low Background Particle / Astroparticle Physics

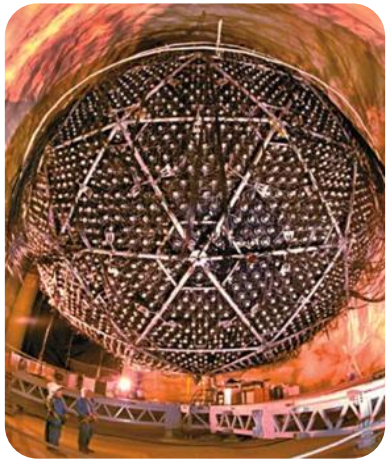
- Direct dark matter searches
- Atmospheric, solar & supernova neutrinos
- Reactor and accelerator neutrinos
- Neutrino-less double beta decay
- Nuclear astrophysics / stellar reactions
- Misc. rare-decay processes

Other ‘Multi-disciplinary’ studies

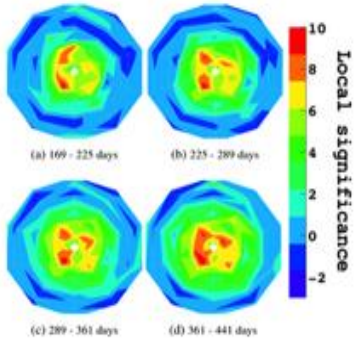
- Pure and applied cosmic ray studies,
- Gravitational waves studies
- Misc. Earth and Environmental Sciences
- Geo-microbiology & life in extreme environs
- Astrobiology and planetary exploration
- Quantum sensors, quantum computing
- Etc…

Dark Matter Studies

Neutrino Studies

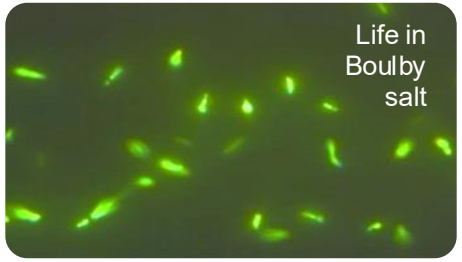


Geology & geophysics



ULB Gamma spectroscopy

Biology, astrobiology and more.



Science and Technology Facilities Council

Boulby Underground Laboratory

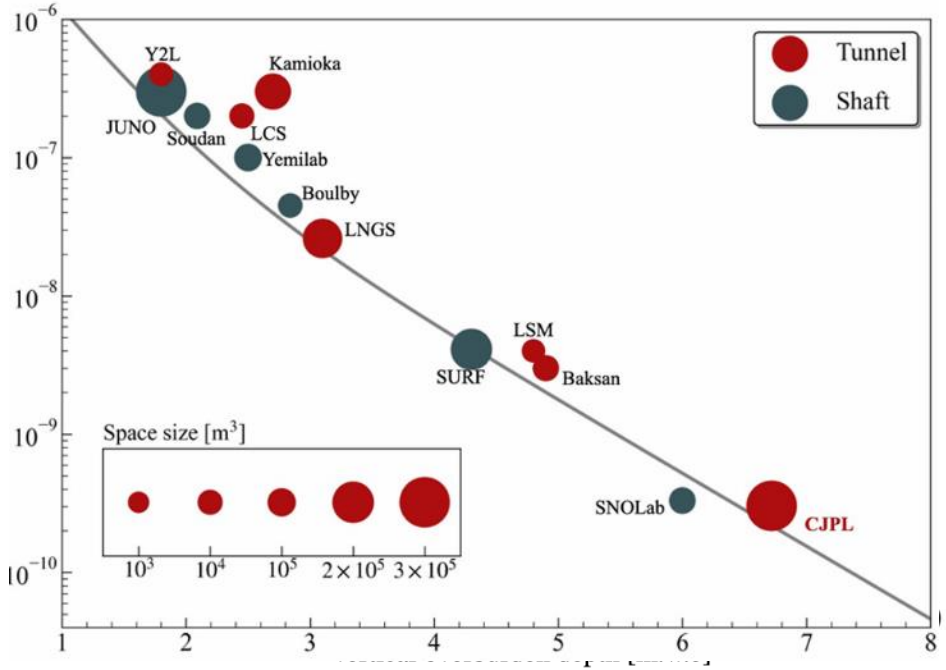
What's needed from an underground lab? (1)

Experimental Space with… **Low Backgrounds…**

Go underground…

Cosmic ray Muons…

- Deep underground facilities provide rock overburden & commensurate reduction in c.r. flux & spallation induced products (neutrons)



Neutrons…

Production from

- c.r. muon spallation
- U/Th fission
- α, n reactions

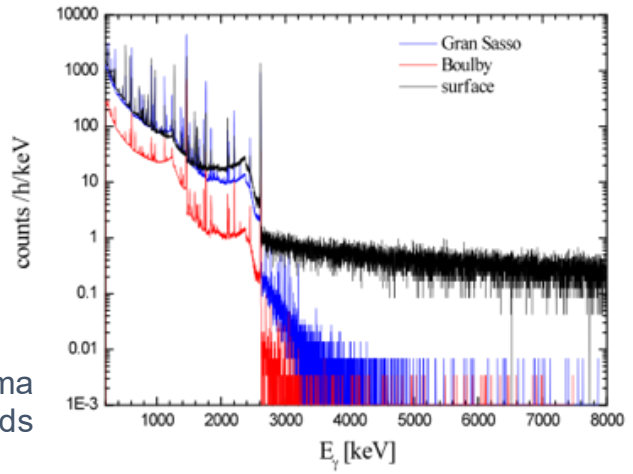
Radon….

- Dependent on local geology & ventilation

Choose low background rock…

Gammas….

- Reduction in γ-ray background at higher energies from c.r. and neutron reduction
- Below 3.5MeV dependent on local geology

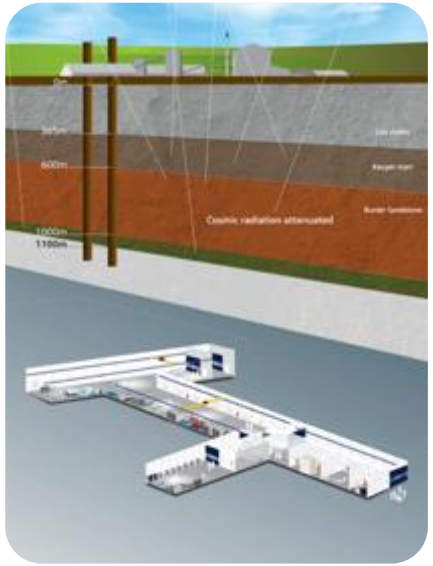


Gamma backgrounds

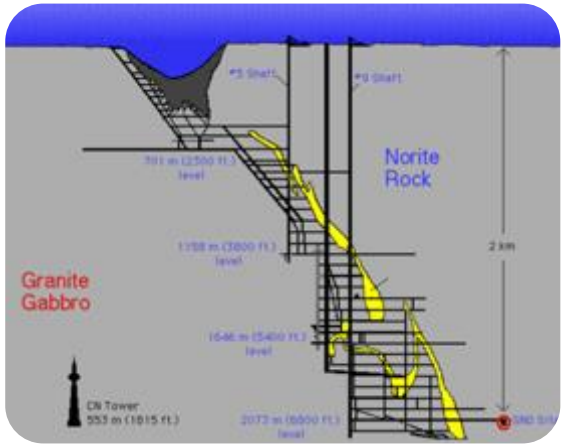
Science and Technology Facilities Council

Boulby Underground Laboratory

Underground Labs around the world….

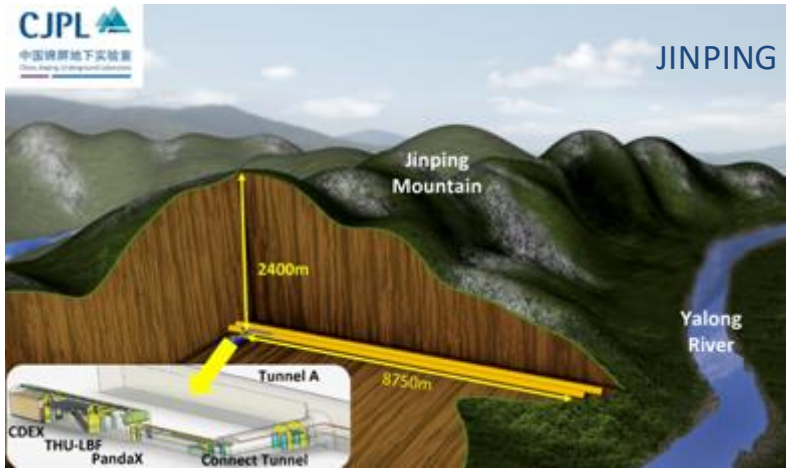


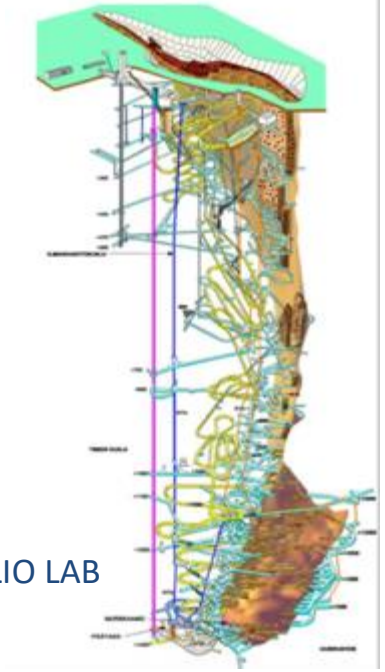
Boulby



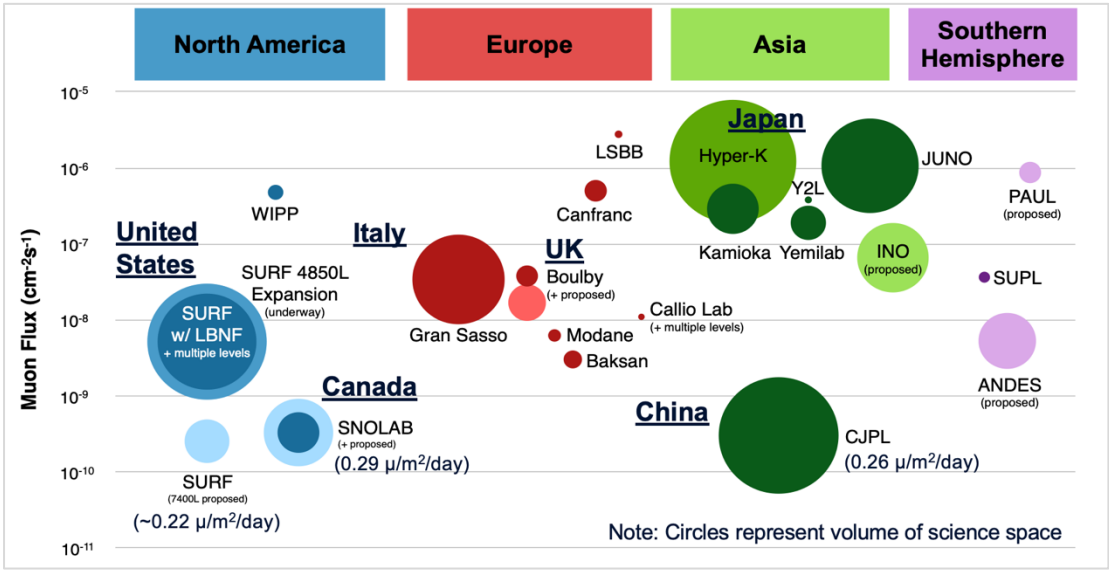
SNOLAB

In mines and under mountains





CALLIO LAB



LNGS

SURF

Science and Technology Facilities Council

Boulby Underground Laboratory

What's needed from an underground lab? (2)

Other Factors:

'A hole in the ground is not a facility!'

Facility Infrastructure, operations and support factors:

- Good surface & underground infrastructure & support facilities
- Reliable utilities: power, ventilation, heat management, water, gases/liquids
- Good Health & Safety and security systems
- Scientific and technical support personnel: design, construction, operation/analysis
- Ancillary science support facilities: low background assay systems, clean rooms workshops etc, etc …

Various other site characteristics that matter to science teams:

- Ease of Access (vertical or horizontal); Max installation size limitations
- Location (neutrino flux from beam/reactor, ease of travel, quality of life)
- Cleanliness, vibration and other interferences
- **Suitable geology / environmental characteristics**

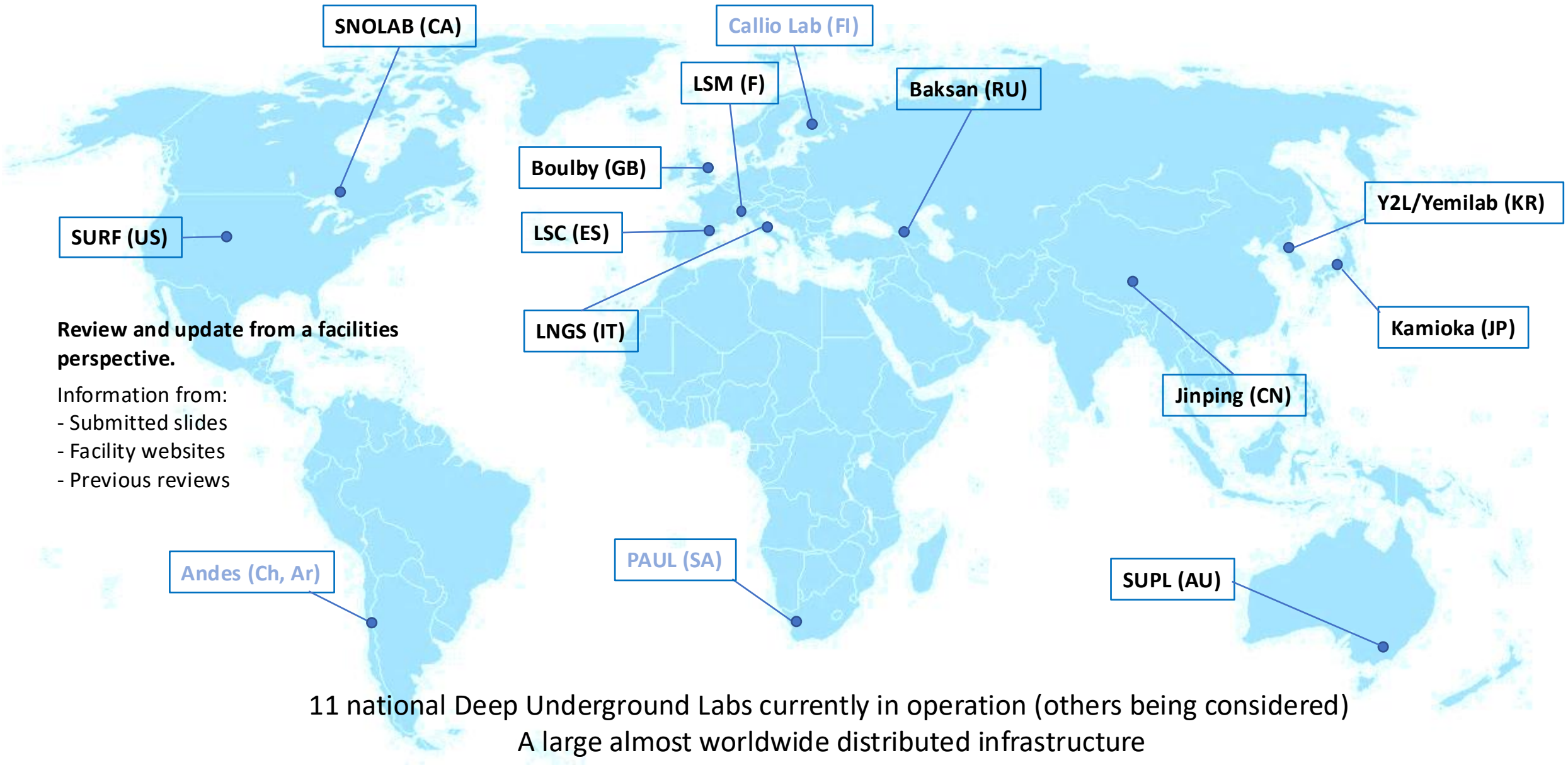
Other non infrastructure-based things can be important too

Local politics & science community: Solid host nation political and financial support, strong local science community involvement and support.

UKRI Science and Technology Facilities Council

Boulby Underground Laboratory

World Deep Underground Science Labs

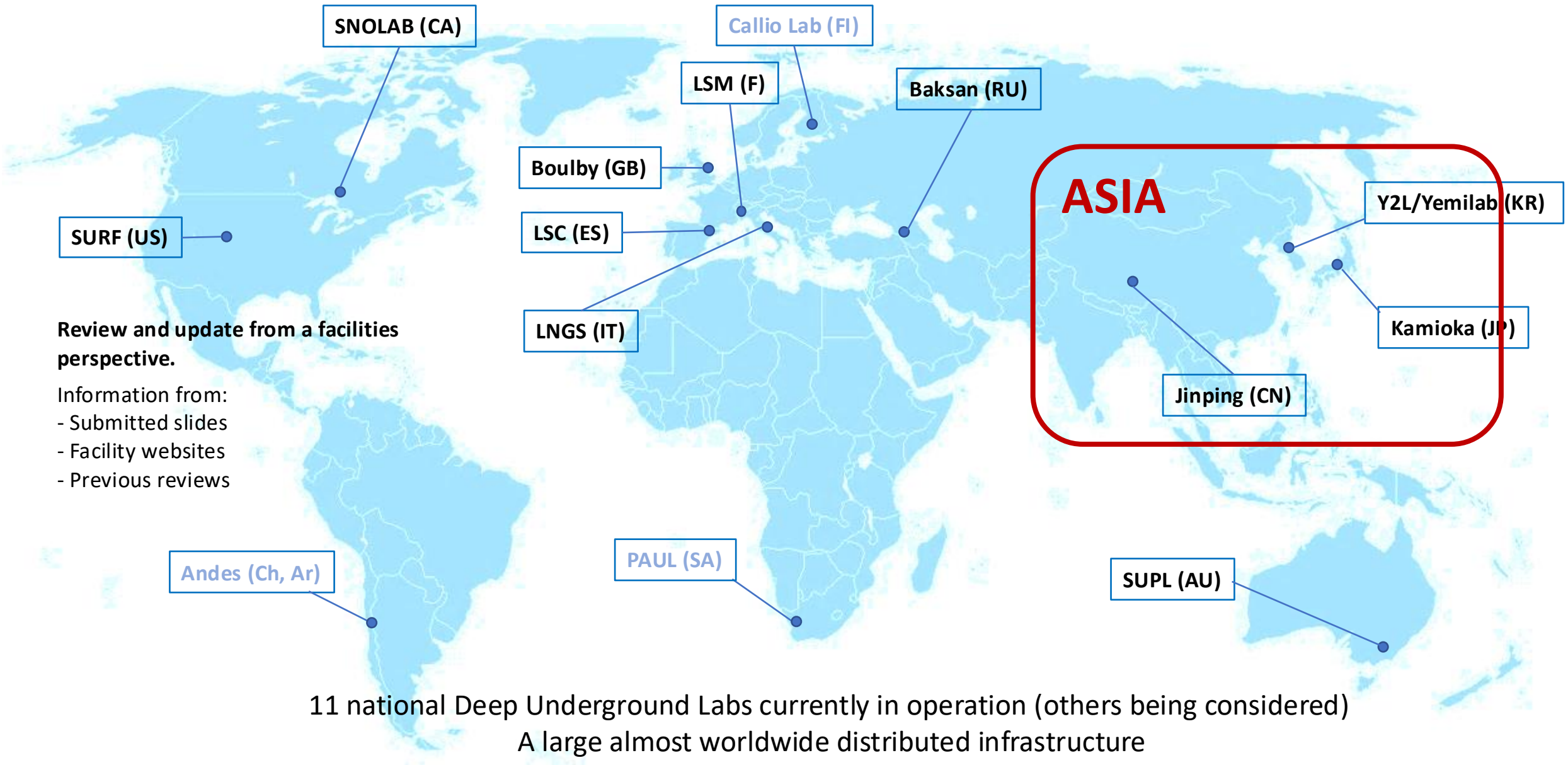


Review and update from a facilities perspective.

Information from:
- Submitted slides
- Facility websites
- Previous reviews

11 national Deep Underground Labs currently in operation (others being considered)
A large almost worldwide distributed infrastructure

World Deep Underground Science Labs



Review and update from a facilities perspective.

Information from:
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11 national Deep Underground Labs currently in operation (others being considered)
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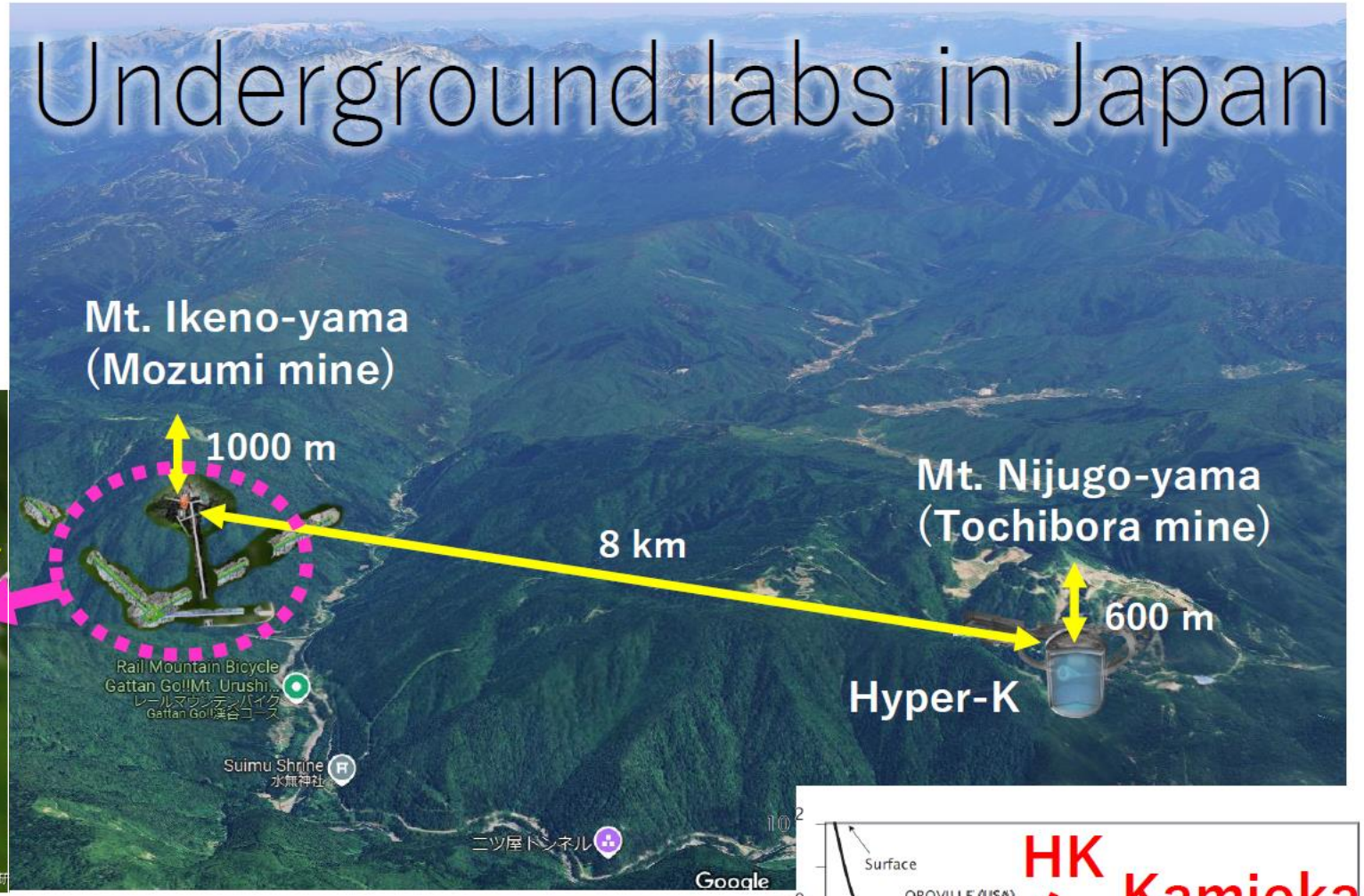
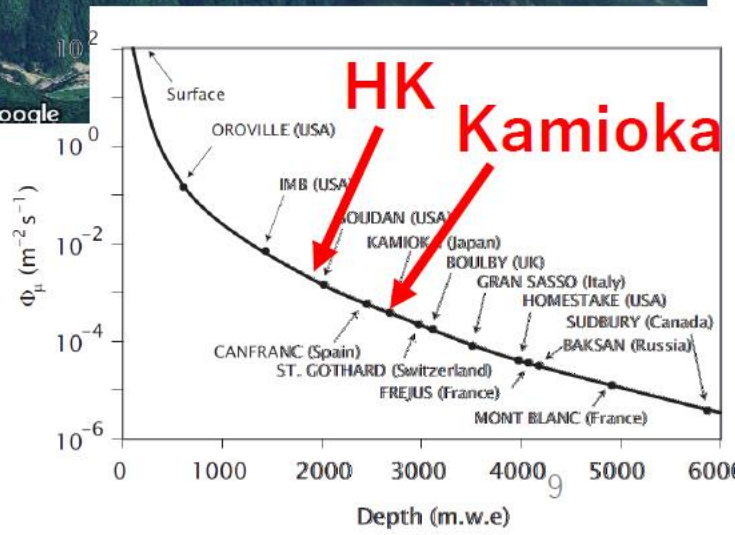
Underground labs in Japan



- Kamioka underground (Mozumi mine)
  - 1000 m overburden
  - Super-K, KamLAND, EGADS, CADLES, NEWAGE, XMASS, KAGRA, CLIO
- Tochibora mine
  - 600 m overburden
  - 8 km far from Mozumi mine.
  - It is now being excavated.



From Takeda, LRT-24

Kamioka underground facilities (Mozumi mine)

KamLAND (Tohoku Univ.)
- 1 kton liquid scintillator detector.
- Reactor, geo, low-energy astrophysical neutrinos, ^{136}Xe $0\nu\beta\beta$ decay.

Super-Kamiokande
- 50 kton Gd-water Cherenkov detector.
- Atmospheric, solar, SN neutrinos, DSNB, proton decay, indirect DM searches, far detector for T2K.

Super-K 2026:
- Running with Gd doping since 2020

CANDLES (Oosaka Univ.)
- CaF_2 scintillator.
- ^{48}Ca $0\nu\beta\beta$ decay.
- Low BG HPGe in Lab-D

XMASS
- 1 ton single-phase LXe detector.
- Direct DM searches.
- Data taking was completed.

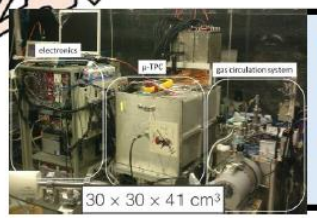
Others in Lab-C
- Two ultra-low BG HPGe

Clean room in storage
- ICP-MS (Agilent7900)

EGADS
- 200 ton Gd-water test tank

Lab-A
AICHAM
Lab-D
Lab-E
Lab-C
Lab-I
Lab-B
Lab-G
Atotsu entrance
100 m

Lab-I
- Three HPGe
- Low-BG α counter
- ICP-MS



NEWAGE (Kobe Univ.)
- Low pressure TPC+MPGD
- Direction-sensitive direct DM searches.

CLIO (Gravitational-wave)
- 100 m × 100 m prototype.

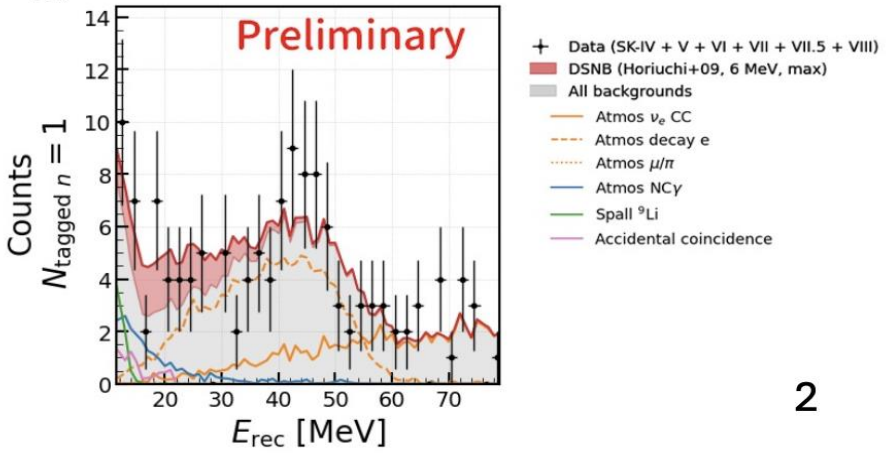
Geophysics
- 100 m × 2 laser strain meter.

From Takeda, LRT-24

Super-Kamiokande in operation w/ Gadolinium doping

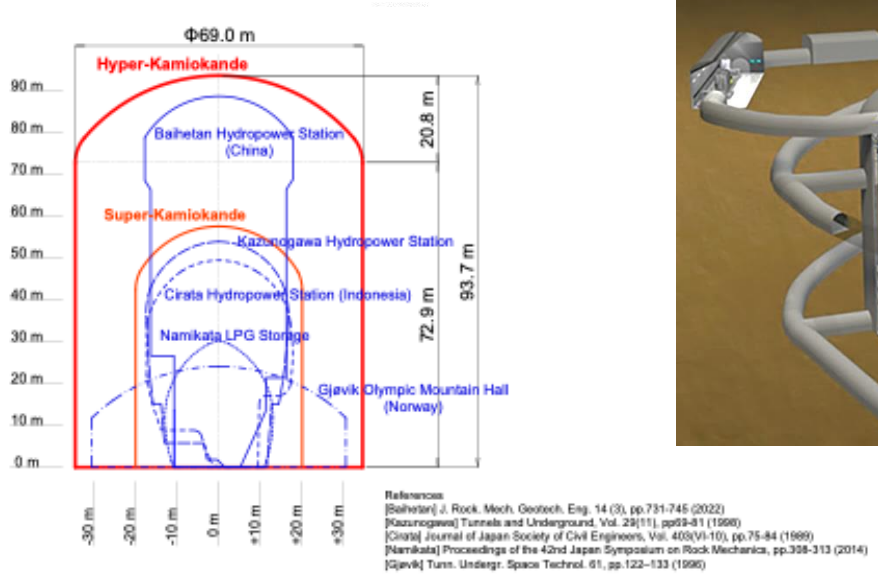
- June 2026, Reports the First Indication of the Diffuse Supernova Neutrino Background(DSNB).
  - 2.6 sigma (99.5% confidence level)
- Continues observations of DSNB, atmospheric and solar neutrinos, T2K, and proton decay searches to yield updated results.

Energy distribution of DSNB candidates

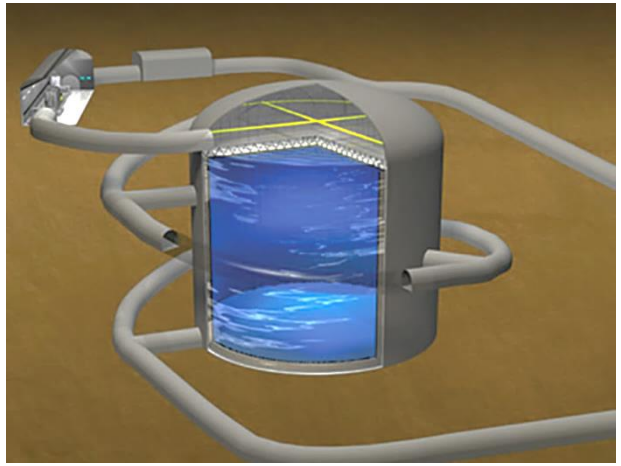


Hyper-Kamiokande
under construction

- Excavation of the detector cavern completed on July 31, 2025.

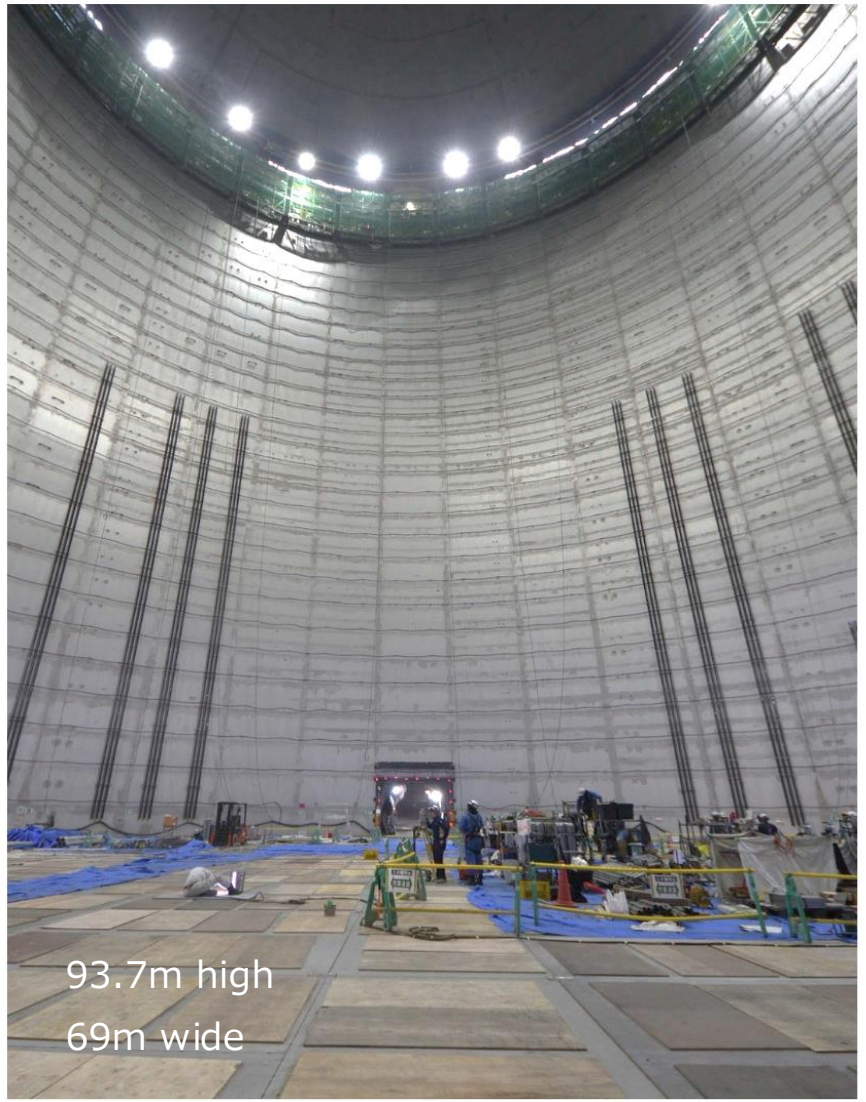


Cross-sectional comparison of major underground rock caverns in Japan and abroad



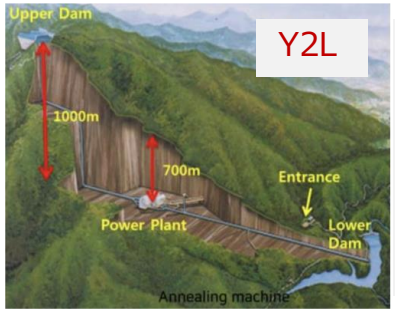
- It is followed by the completion of detector tank lining of July 31, 2026.
- Full-scale operations are scheduled to begin in 2028.

Hyper-K Tank Lining (July 24, 2026)



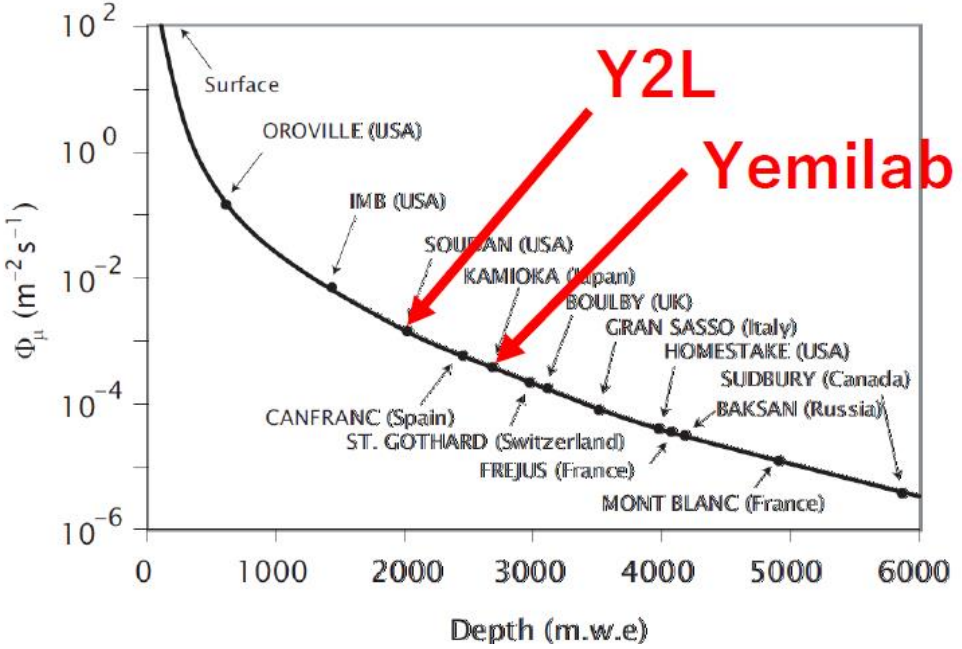
Underground labs in Korea

- **Yangyang Underground Laboratory (Y2L):** (2003+)
  - Yangyang Pumped Storage Power plant
  - 700 m overburden
  - ~150 km from Seoul



Since 2003
- KIMS (DM)
- COSINE (DM)
- AMoRE (0vBB)
- HPGe

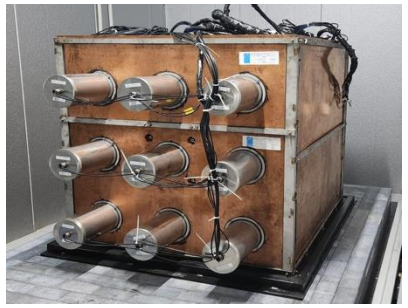
- **Yemilab:** (2022+)
  - Handeok mine
  - 1,000 m overburden
  - ~150 km from IBS-HQ



Mu-on flux

Yemilab

- Completed in September 2022.
- 1,000 m depth and 3,000 m^3 exclusive experimental area
- Y2L facilities are being relocated to YemiLab.
- Large halls for **AMoRE-II**, LSC w/cyclotron/accelerator and purification.
- Ladder halls for **COSINE**, HPGe/Alpha, Refuge, etc.



Institute for Basic Science
(COSINE-100U)

Institute for Basic Science
(νEYE, proposed)

Institute for Basic Science
(YUNA@K, proposed)

NIMS
(μGravity)

Institute for Basic Science
(AMoRE-II)

Space Lintech
(Space medicine)

KIGAMS
(Space Planting)

KMA
(Earthquake)

Institute for Basic Science
(HPGe, Alpha counter)

KAERI
(Env. Radiation)

KIGAMS
(Geology)

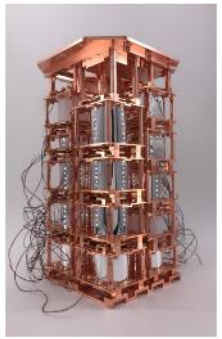
Kyungpook National University
(KAPAE, $0\nu\beta\beta$ decay R&D)

Multi-purpose
4 Institutes
1 University
1 Company (startup)
→ 11 research topics

Jungho So, 2026

Yemilab

CENTER FOR UNDERGROUND PHYSICS



Nuclear and Particle Physics:

- **WIMP: COSINE-100U @ Yemilab**
  - Lower temperature (-30°C)
  - Experiment will begin in 2025.
- **0νDBD: AMoRE-II @ Yemilab**
  - Large cryostat is under testing.
  - Experiment will begin in 2026.

The Rn issue in summer

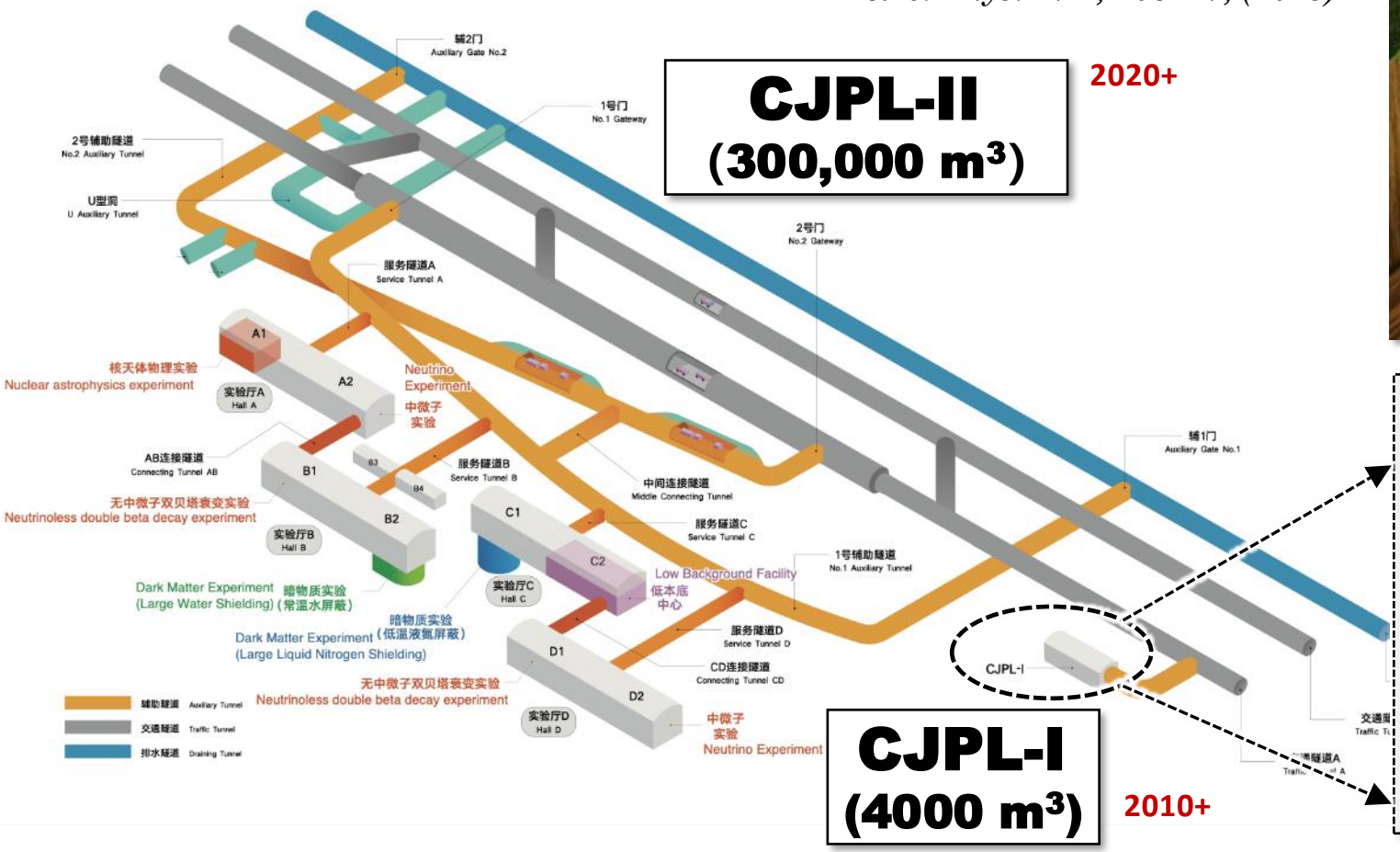
- Avg. Rn level June ~ September has been decreased in 2026.
  - Improve the active ventilation through the ramp way.
  - Major contribution by heat blowers.
  - Two vertical shaft fans helped the air circulation in summer.
  - We can control the **Rn level around 100 Bq/m³ annually**.

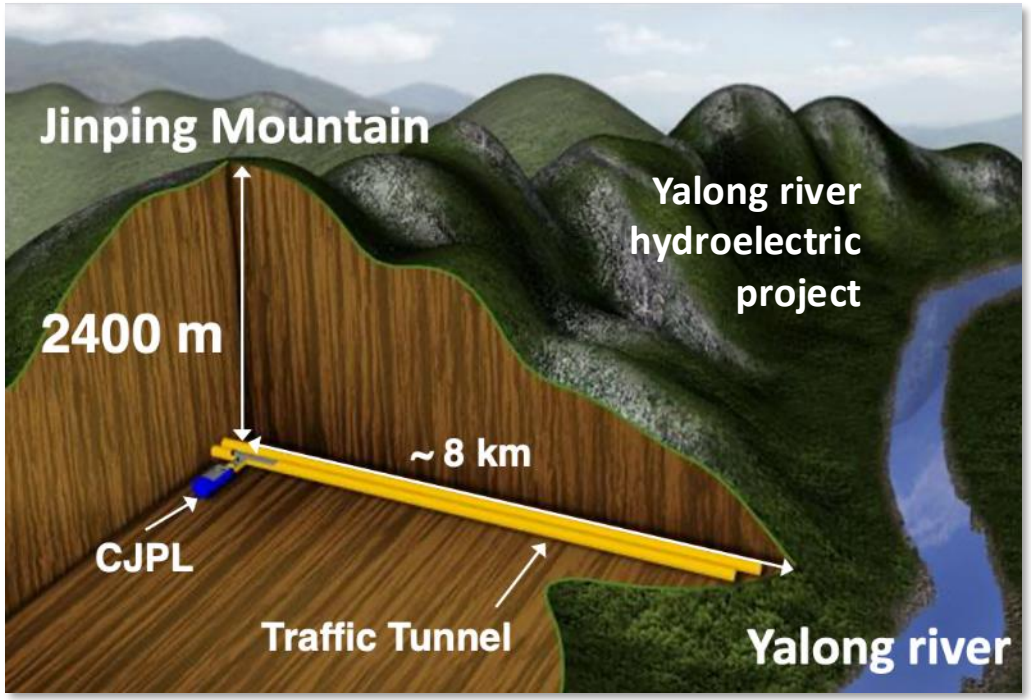
AMoRE Hall

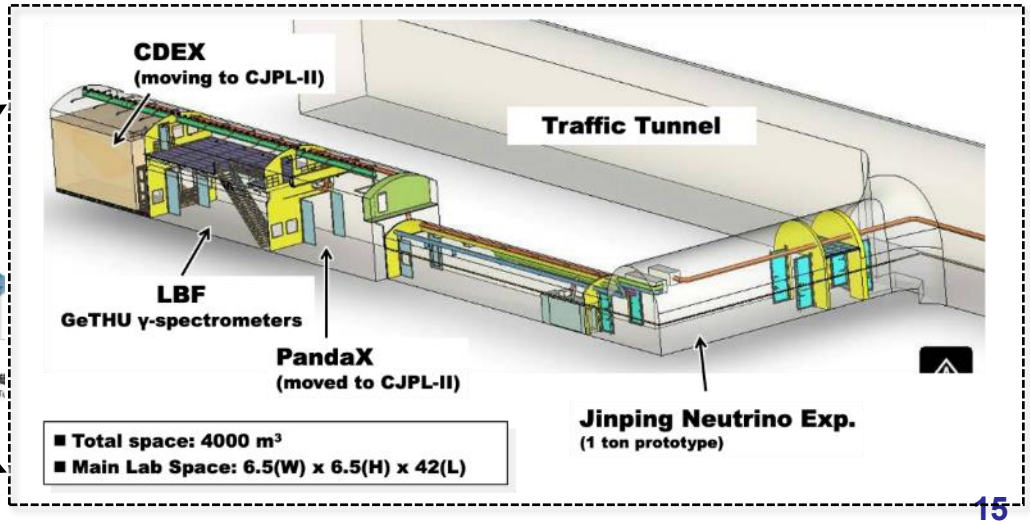
China Jinping Underground Laboratory (CJPL)

- Rock overburden 2400 m
- Muon flux 3.03×10^{-10} cm^{-2}s^{-1}
- Experimental space >330,000 m^3

Astro. Phys. 172 , 103147, (2025)



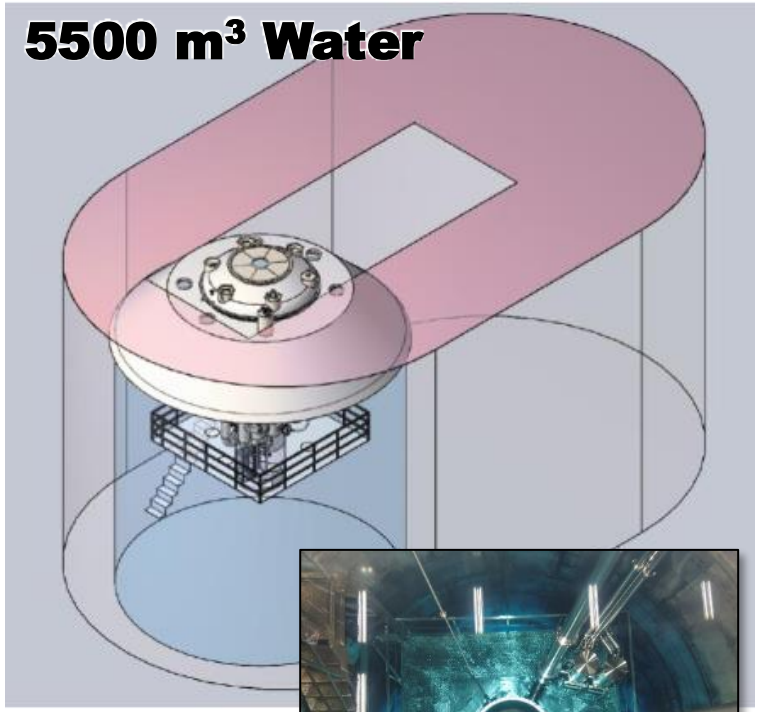


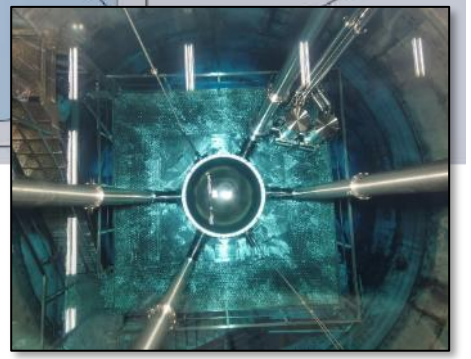


TAUP XICHANG

Large Shielding Facilities at CJPL-II

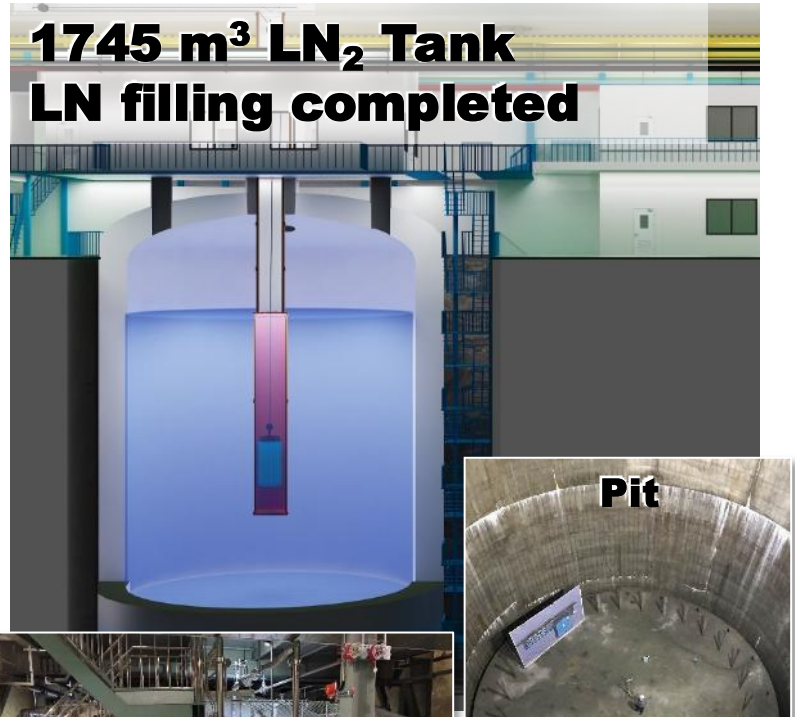
- **Large Water Shielding in B2-Hall**
- **For PandaX LXe-TPC experiment**





Look at the PandaX det.

- **Large LN_2 Shielding in C1-Hall**
- **For CDEX HPGe DM & 0νββ experiment**



- **Large PE Shielding Room in C2-Hall**
- **Total 16 low-BG HPGe γ spectrometers**

GeTHU
- 15 low-BG γ spectrometers

ARGUS
- Ultralow-BG γ spectrometer

Research Activities at CJPL-II

JUNA
Jinping Underground Nuclear Astrophysics experiment

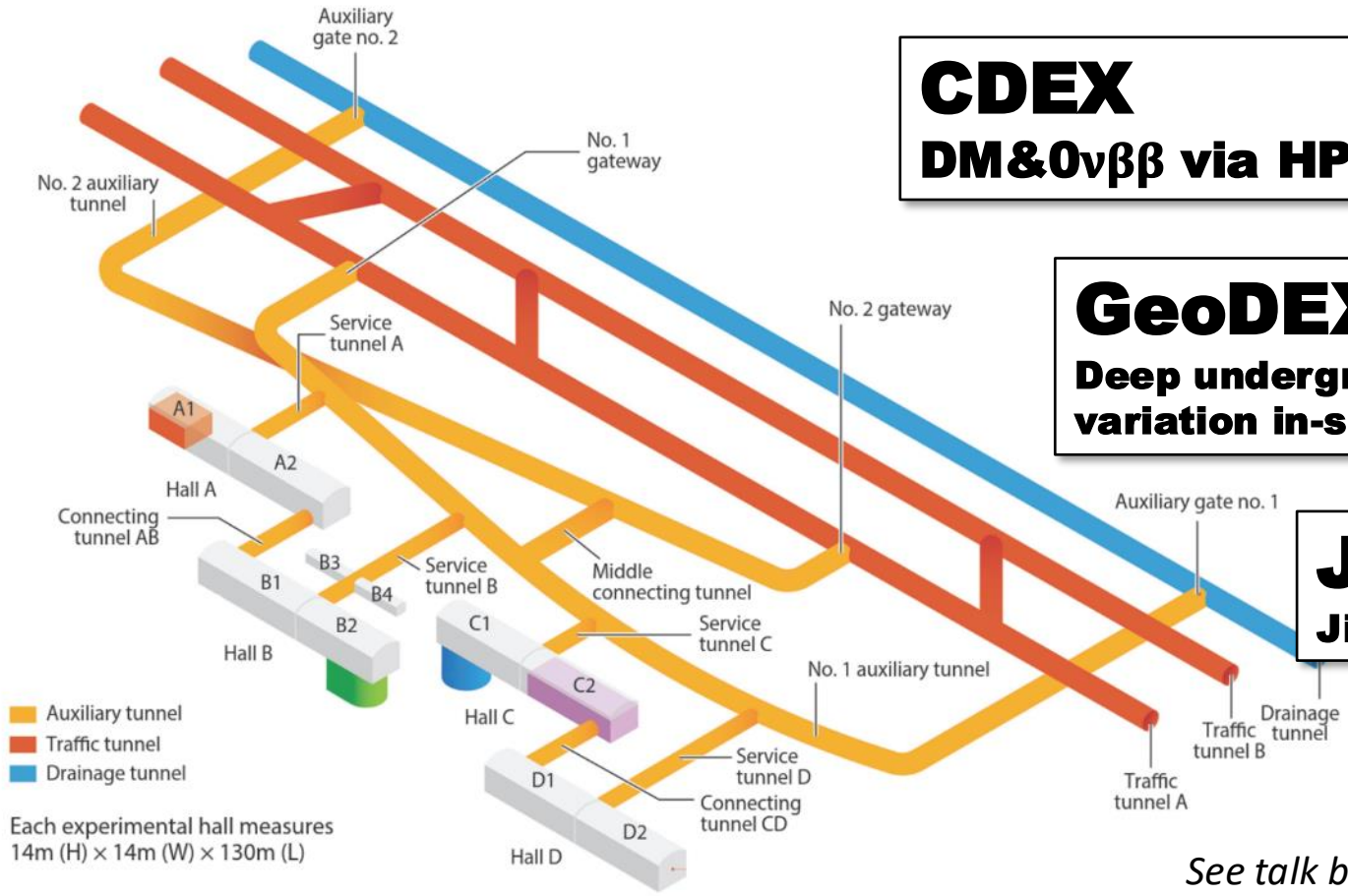
PandaX
DM&0νββ via LXe-TPC

PandaX-4T since 2020
PandaX-20T to come soon

CDEX – 300/1T to come soon

CDEX
DM&0νββ via HPGe

And more:
CUPID-CJPL
Mo-100 0νββ
NvDEX
Se-86 0νββ
ICSER
Integrated Circuit Soft Error Research
...



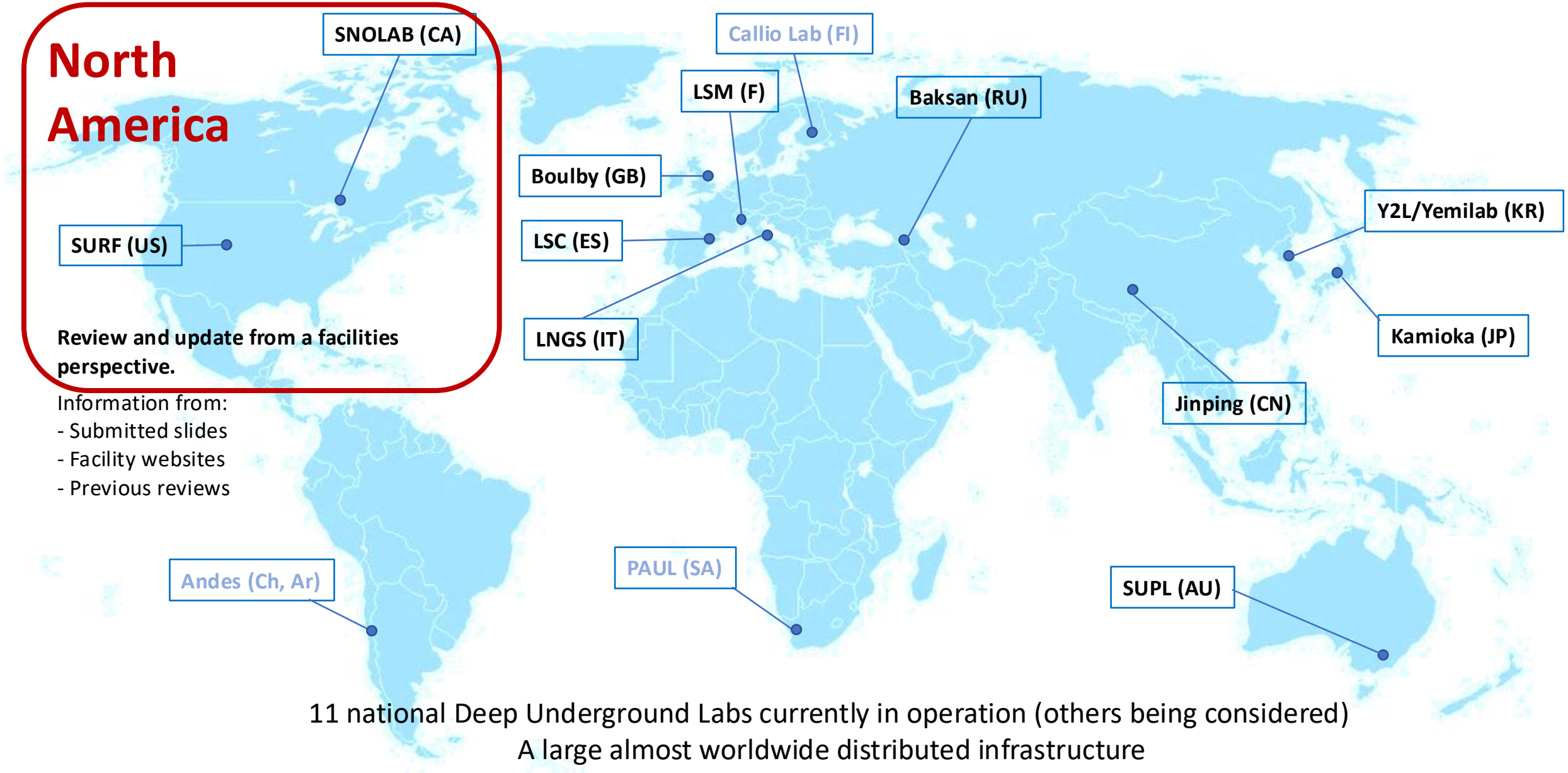
GeoDEX
Deep underground geologic time variation in-situ detector experiment

JNE
Jinping Neutrino Program

See talk by Zeng Zhi – Monday TAUP 25

CJPL welcomes researchers worldwide to submit proposals!

World Deep Underground Science Labs



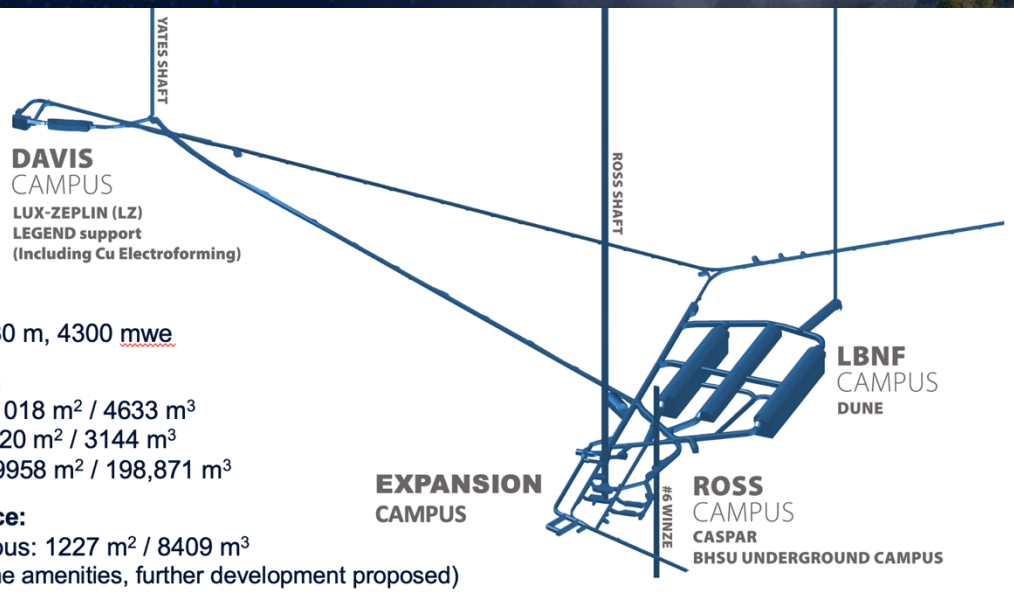
11 national Deep Underground Labs currently in operation (others being considered)
A large almost worldwide distributed infrastructure

SANFORD UNDERGROUND RESEARCH FACILITY

Sanford Underground Research Facility (SURF)
Homestake mine, Lead, South Dakota, USA

SURF Overview

Existing Science Facilities



Depth (4850L): 1480 m, 4300 mwe

Laboratory Space:
- Davis Campus: 1018 m^2 / 4633 m^3
- Ross Campus: 920 m^2 / 3144 m^3
- LBNF Campus: 9958 m^2 / 198,871 m^3

New Existing Space:
- Expansion Campus: 1227 m^2 / 8409 m^3
  (existing with some amenities, further development proposed)

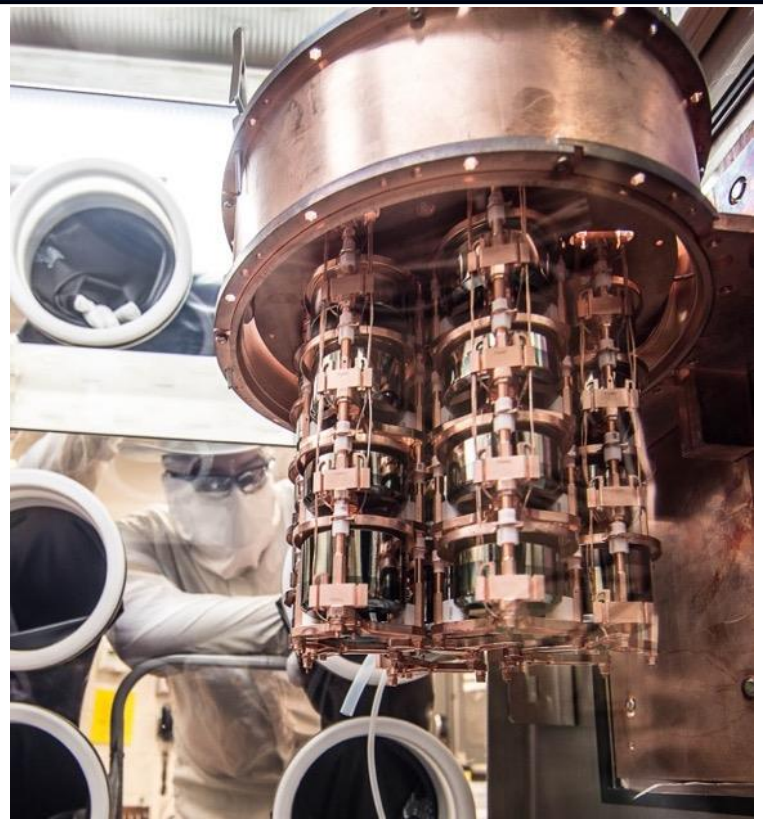
Jaret Heise, Science Director
jaret@sanfordlab.org

SURF Science Program – Current Physics Highlights

Strong and diverse program with exciting future

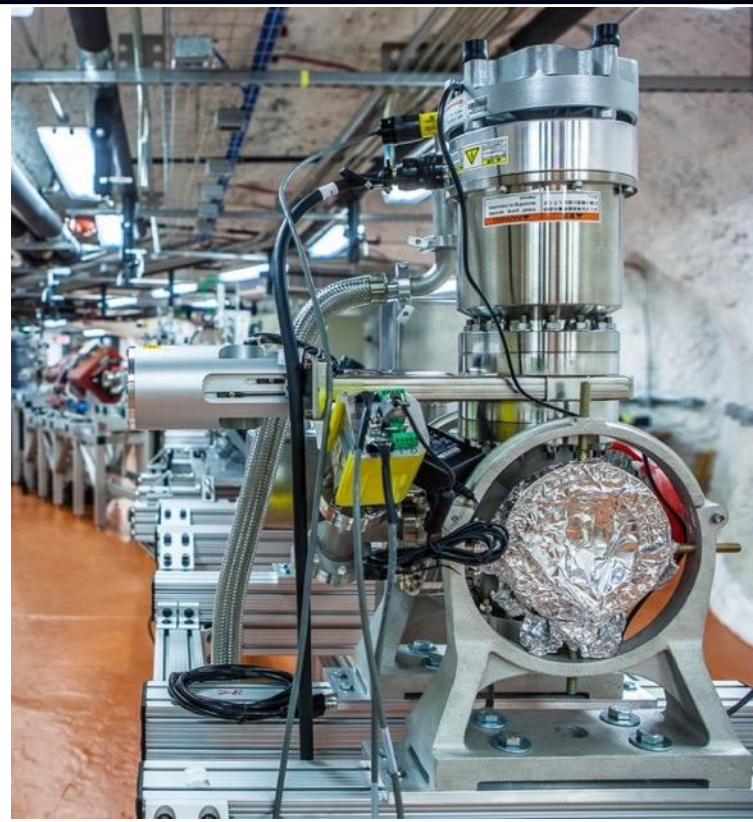
LUX-ZEPLIN (LZ)

- Direct search for **dark matter** using 10 tonnes xenon
- World-leading WIMP-search results since 2022, Sep 2026 HENR event (!)



MAJORANA DEMONSTRATOR (MJD)

- Investigate **neutrinoless double-beta decay** using 44 kg Ge
- Ge-76 DBD and Ta-180 decay complete, Cu e-forming continues



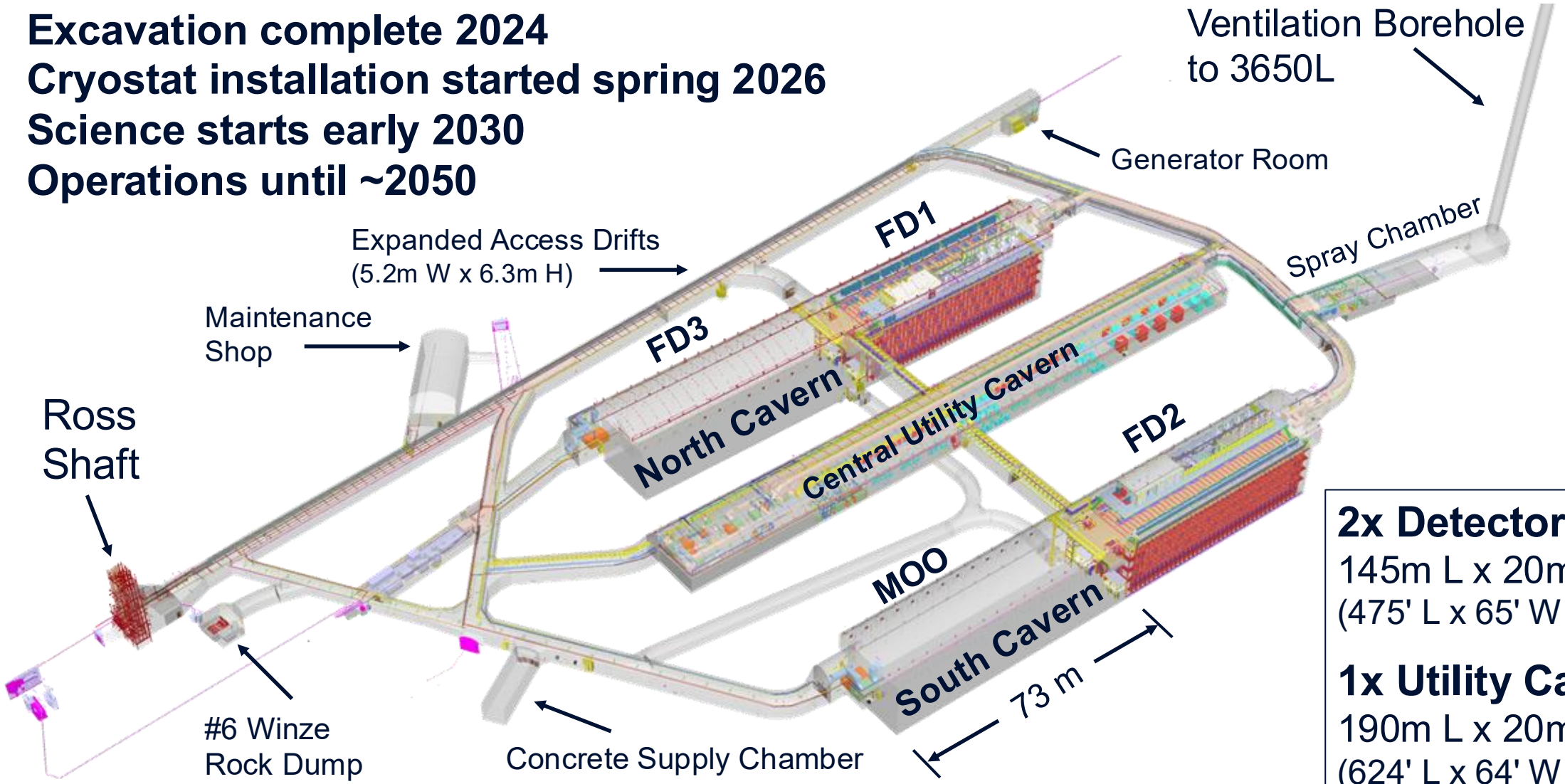
CASPAR

- Stellar fusion reactions to study **nucleosynthesis** using accelerator
- Initial phase 2015-2021, physics data resumed 2026 (^{19}F)

Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)

Excavation complete 2024
Cryostat installation started spring 2026
Science starts early 2030
Operations until ~2050

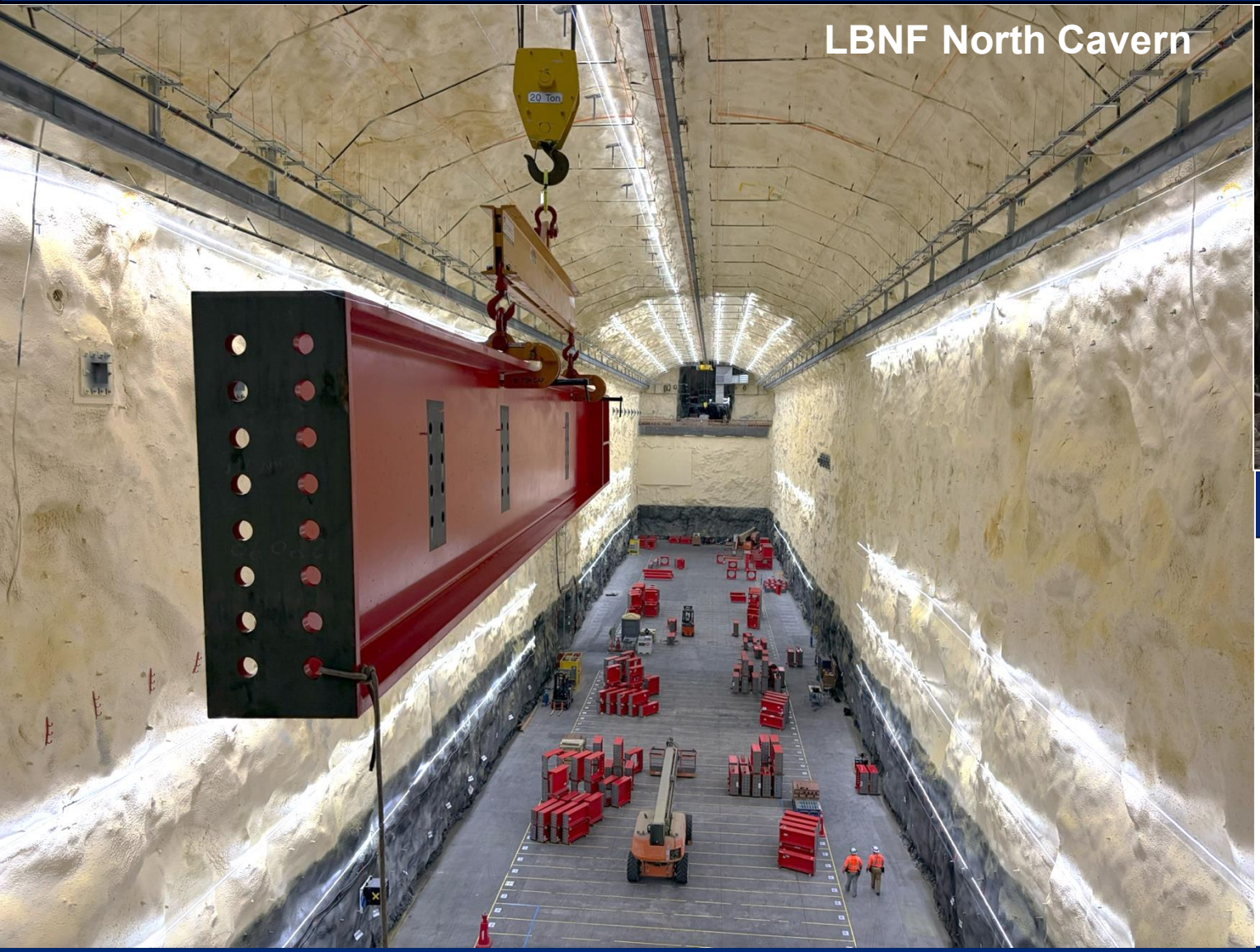


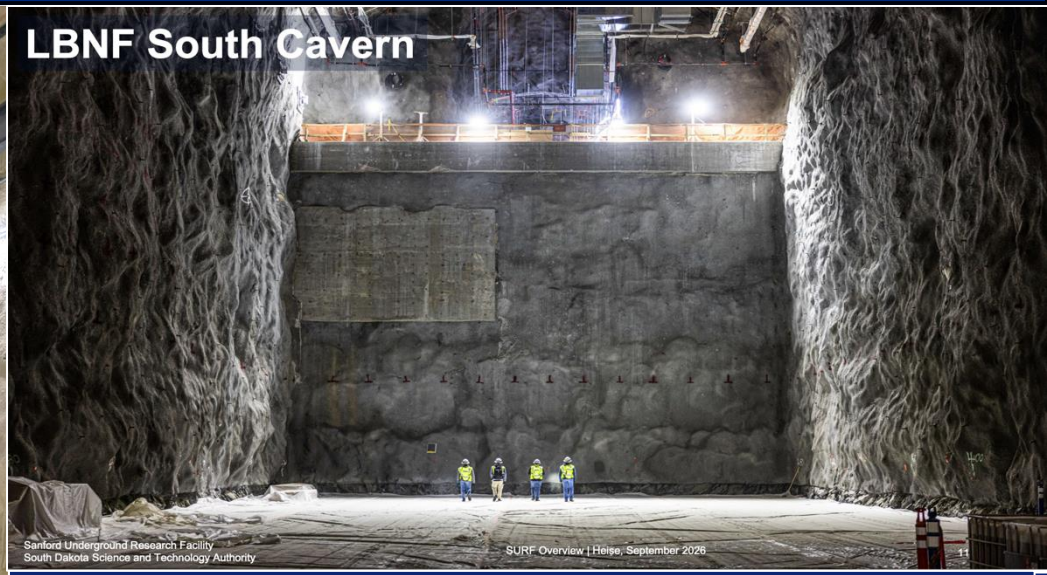
2x Detector Caverns:
145m L x 20m W x 28m H
(475' L x 65' W x 92' H)

1x Utility Cavern:
190m L x 20m W x 11m H
(624' L x 64' W x 37' H)

Long-Baseline Neutrino Facility (LBNF)

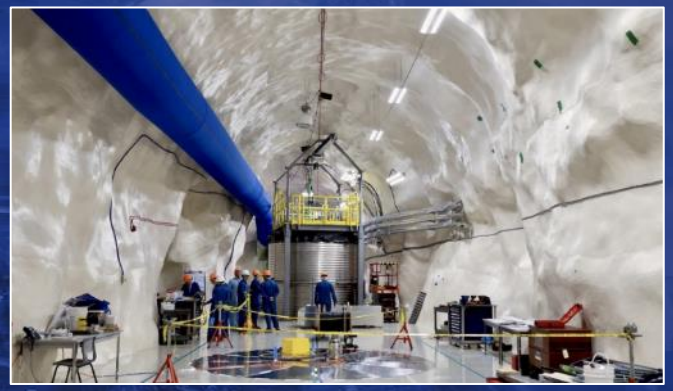
LBNF will host the Deep Underground Neutrino Experiment (DUNE)



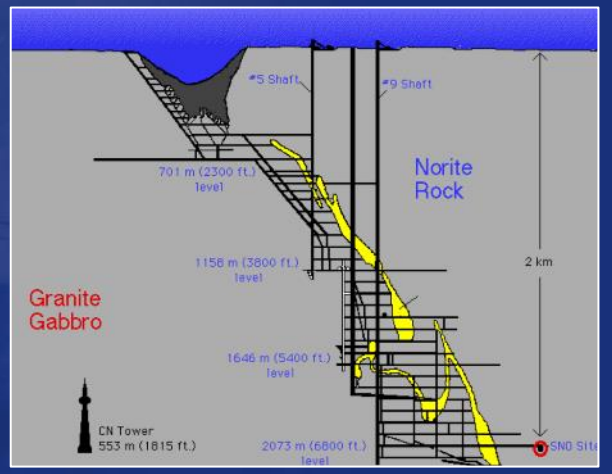


SURF Summary

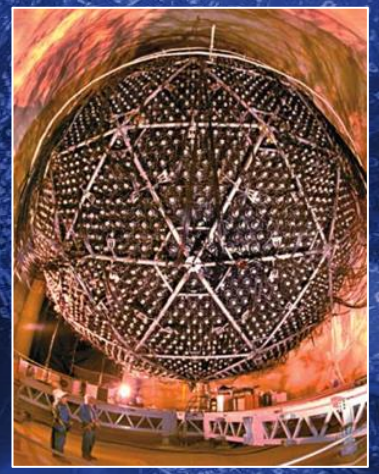
- **SURF offers world-class service to the underground science community:**
  - SURF attributes attract **world-leading** experiments and scientists from **diverse scientific communities**.
  - SURF has **proven track record** of enabling high-impact science by leveraging strong **institutional partnerships**.
- **SURF wants to host future world-leading experiments:**
  - LBNF excavation done, outfitting started. **DOE "Module of Opportunity"** expanded physics prog.
  - Construction underway to **increase underground laboratory space**, plans advancing for new large caverns on 4850L on timeframe of **next-generation neutrino and dark matter experiments (~2030s)**.
  - Call for **Letters of Interest (LOIs)** re-affirmed prospective experiments and identified **new avenues**. New facilities in planning (**Quantum User Facility**) and consideration (Vertical Facility).
  - SURF is **deep laboratory** site and offers **largest footprint** in the world for scientific pursuits.
  - **Many options to host future initiatives – big or small!**



Creighton mine, Sudbury
Ontario

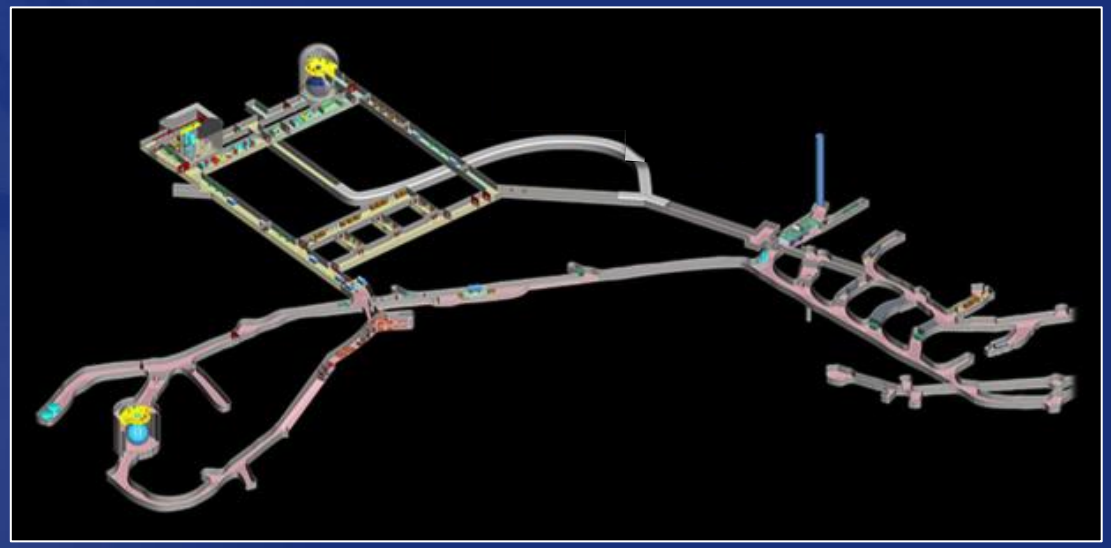


SNOLAB
Status Update



SNO, SNO+
and more…

Depth 2070m (6010mwe)
Volume 37,241m^3



Deep Underground Science Laboratory
Vale‘s Creighton mine, Sudbury
Northern Ontario, Canada

SNOLAB Science Program
Broad & Multidisciplinary

Free space
in Cryopit

Carleton University · VALE · Université de Montréal · University of Alberta · Laurentian University / Université Laurentienne · Queen's

Science Strategy

Increase our understanding of the particles and forces that have shaped the universe.

- What is the nature of dark matter?
- What is the nature of the neutrino?

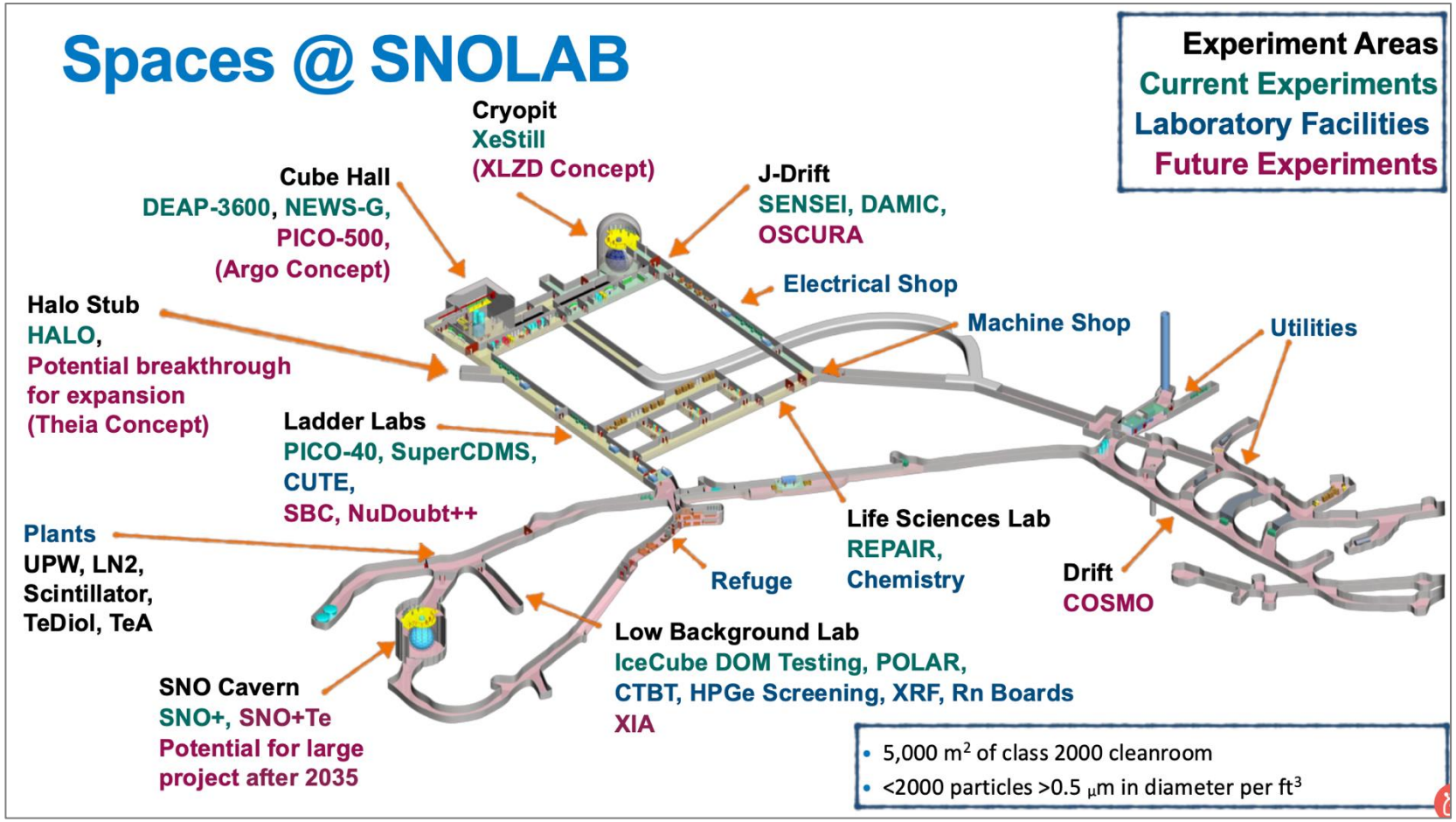
Continue to collaborate in scientific research requiring deep underground facilities.

- Neutrino observatories (solar, supernovae, geo, reactor, etc.)
- Effects of radiation on biological systems
- Environmental monitoring (nuclear non-proliferation, etc.)

Pursue new collaborations and opportunities in emerging areas of underground science

- Quantum technologies (quantum computers, sensors, and materials)

Become an intellectual hub that fosters collaboration and connection.



(Jodie Cooley 2026)

SNOLAB's low-background capabilities

SNOLAB provides world-leading low-background measurement capabilities in its surface and underground laboratories, including:

ICP-MS
Measures ultra-trace elements and isotopes in material samples.

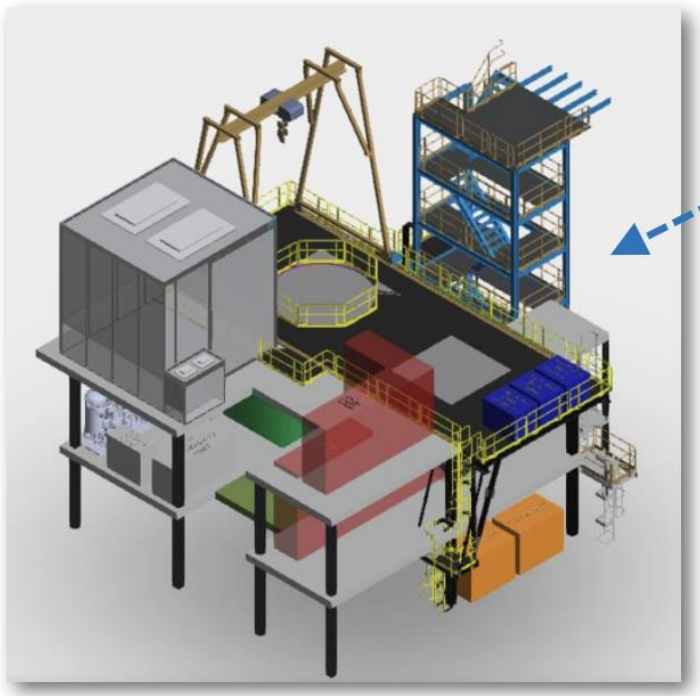
XIA UltraLo-1800's (x2)
Detect alpha emission from samples to assess surface contamination.

Radon Emanation (x2)
Manipulate & measure radon to assay materials and study trapping.

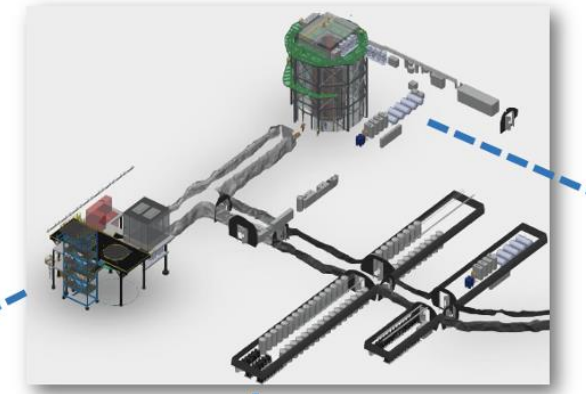
HPGe Detectors (x6)
Perform high-sensitivity material screening for bulk radioactive contamination.

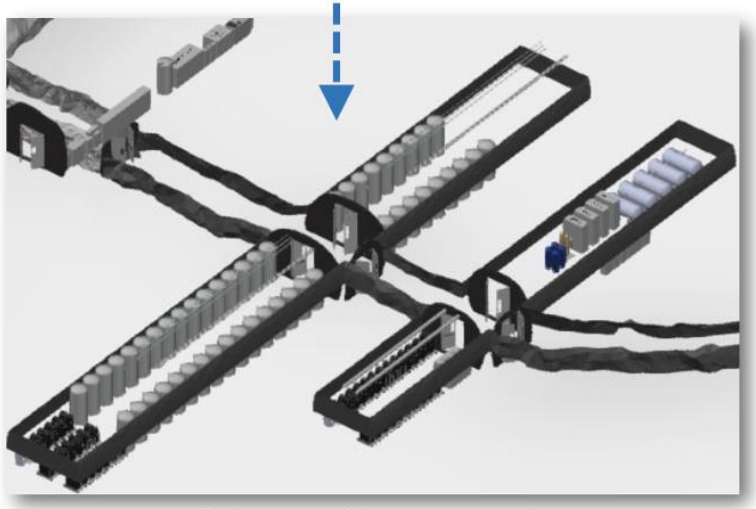
See I. Lawson's talk on Sep 22 for more details.

XLZD @ SNOLAB Concept



Xenon Process Systems
& Clean Assembly Areas





Xenon Storage &
Recovery

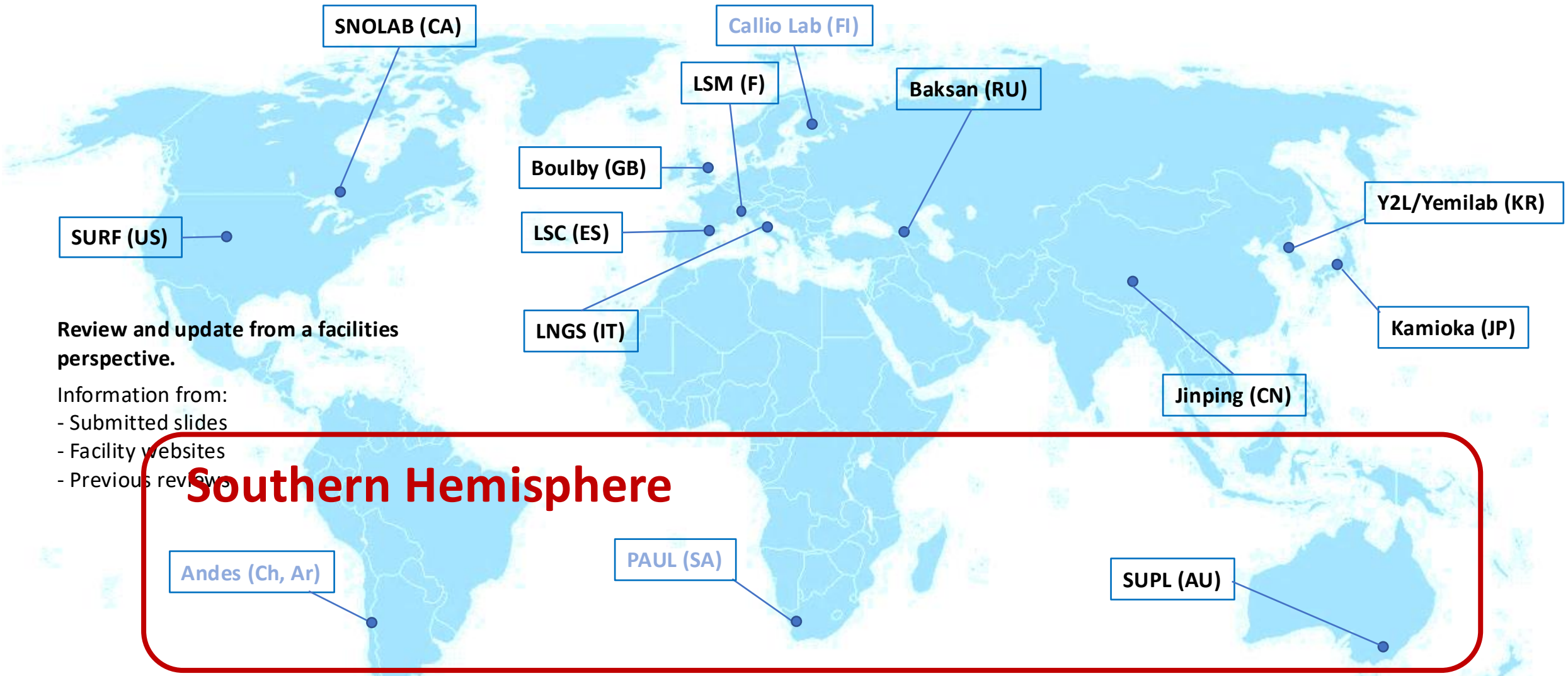
New Funding to Advance XLZD Design

SNOLAB received $1.2M from CFI to advance the XLZD@SNOLAB design:

- **Cryostat:** understand how to build the XLZD cryostat in the SNOLAB Cryopit.
- **Heat Rejection:** develop the chilled-water system needed to support XLZD cryogenic operations and assess associated oxygen-deficiency hazards.
- **Xenon Storage & Recovery:** develop solutions for underground storage and recovery of up to 100 tonnes of xenon.
- **Logistics:** increase capacity for movement of materials and equipment into SNOLAB.

Detector, Shielding Tank
& Cooling Systems

World Deep Underground Science Labs



Review and update from a facilities perspective.

Information from:
- Submitted slides
- Facility websites
- Previous reviews

11 national Deep Underground Labs currently in operation (others being considered)
A large almost worldwide distributed infrastructure

Stawell Underground Physics Laboratory

- **Operational** since October 2023.
- **Located** within Stawell Gold Mines, operational mine ~2.5 hours west of Melbourne, Victoria, Australia.
- **Research Space:** 260m^2 / 2500m^3
- **Radon:** Limited access to 10 Bq/m^3 from a surface air line.

Depth
1025m rock over burden

M.W.E.
2900

Relative Humidity
40-70%

Temperature
21^{O}C +/- 2

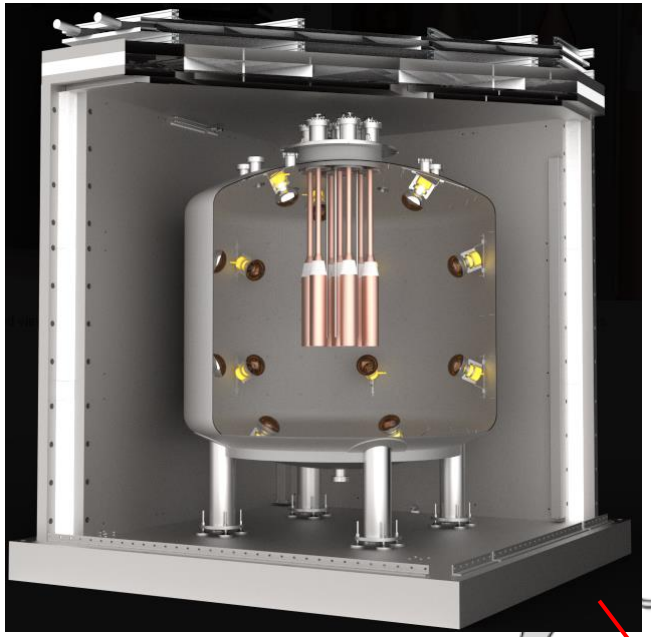
Average radon concentration
450 Bq/m^3

Total muon flux
3.6x10^{-8}/cm^2/s

Type of access
Helical drive-in via operational mine

Figure 1 – Stawell's location relative to key capital cities

Stawell Underground Physics Laboratory



CELLAR

Cryogenic Facility
Proteox MX dilution fridge
Operational 2026.
Research Program:

- Quantum technologies
- Low mass dark matter
- Gravitational waves

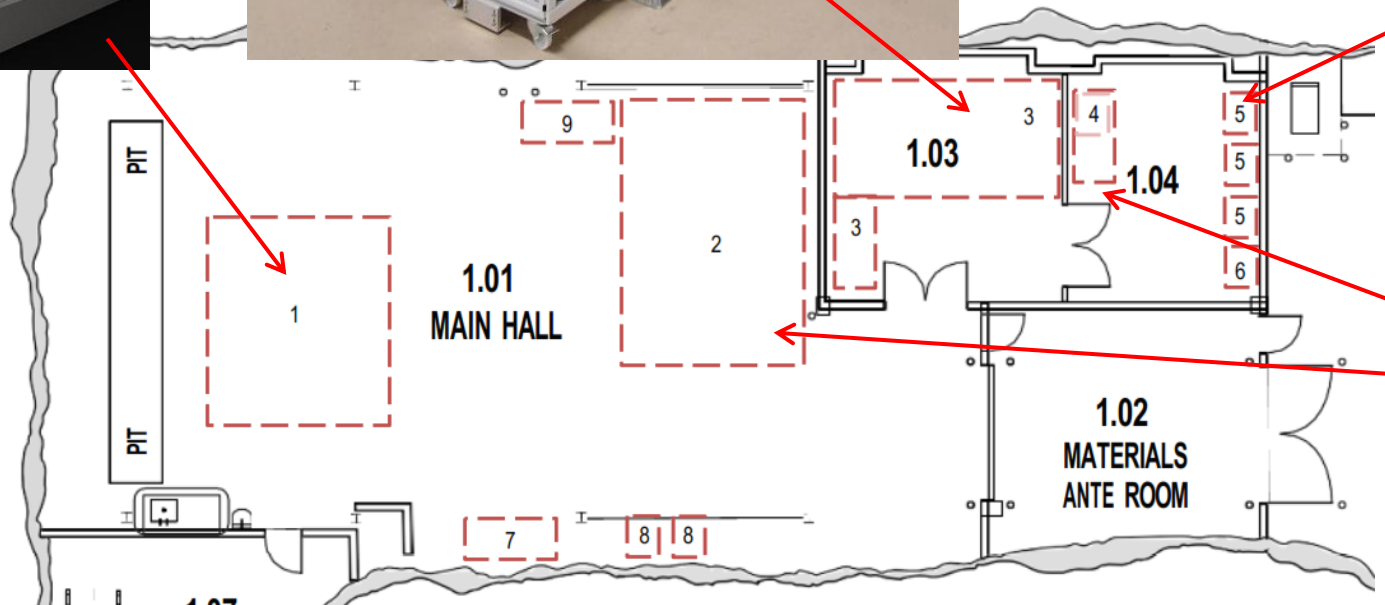
Materials Screening

Future proposed capability.

SABRE South

Direct detection dark matter experiment.
Installation and construction phase.

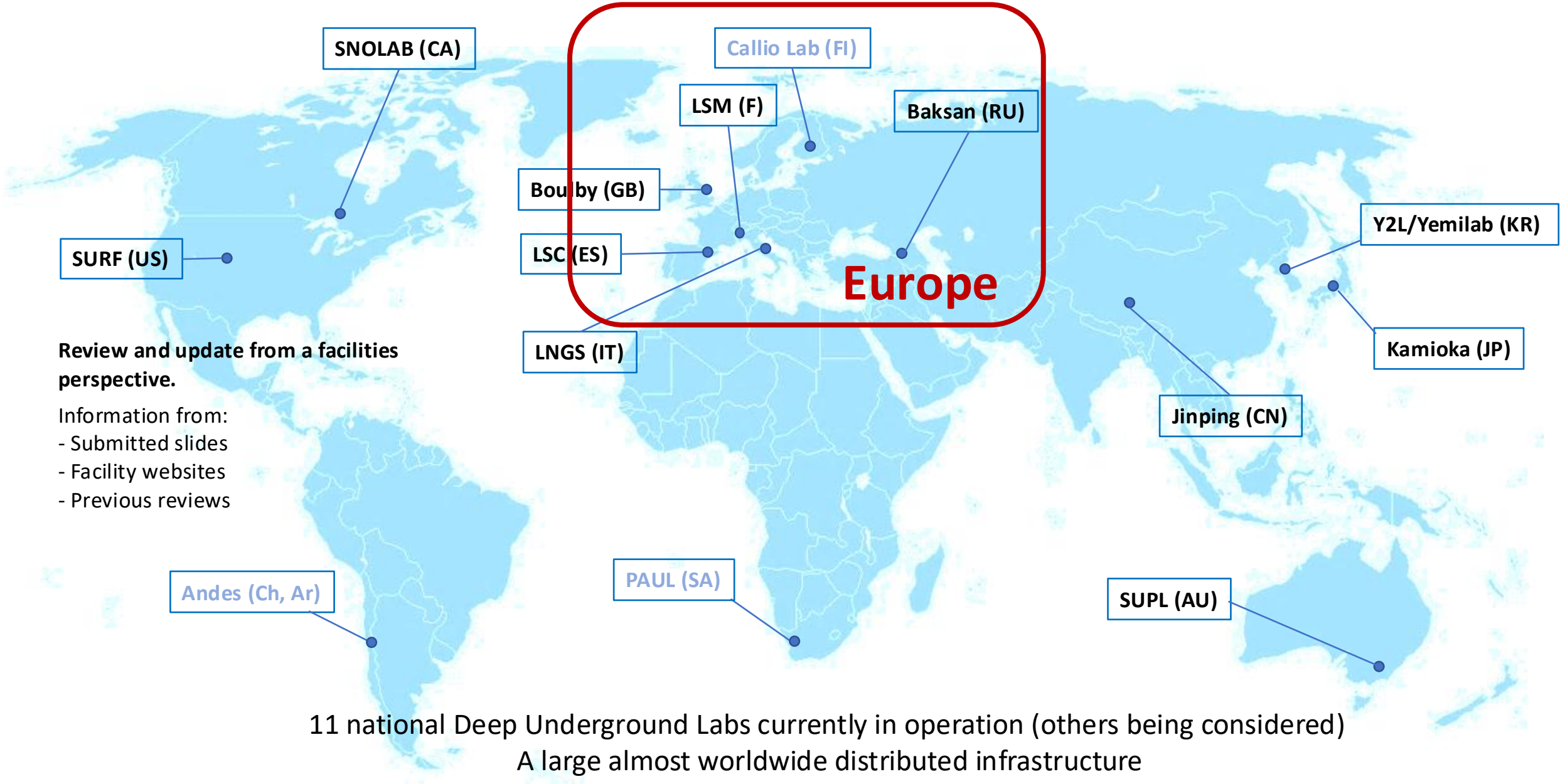
Trial Assembly
Complete



Future Proposals

Radiation biology facilities.
Clean room 20m^2.

World Deep Underground Science Labs



Review and update from a facilities perspective.

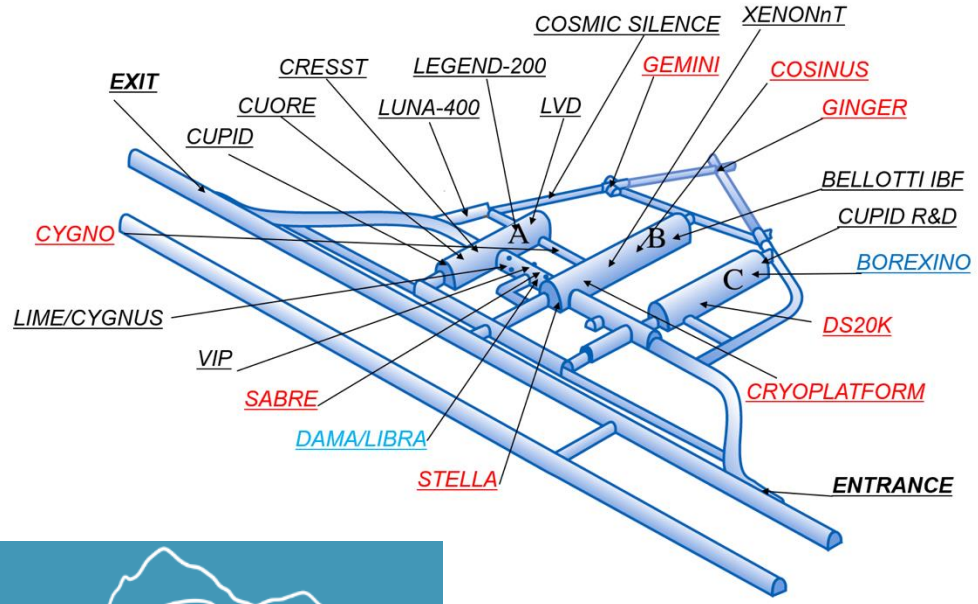
Information from:
- Submitted slides
- Facility websites
- Previous reviews

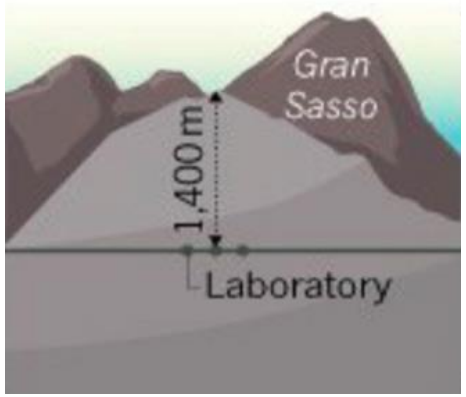
11 national Deep Underground Labs currently in operation (others being considered)
A large almost worldwide distributed infrastructure

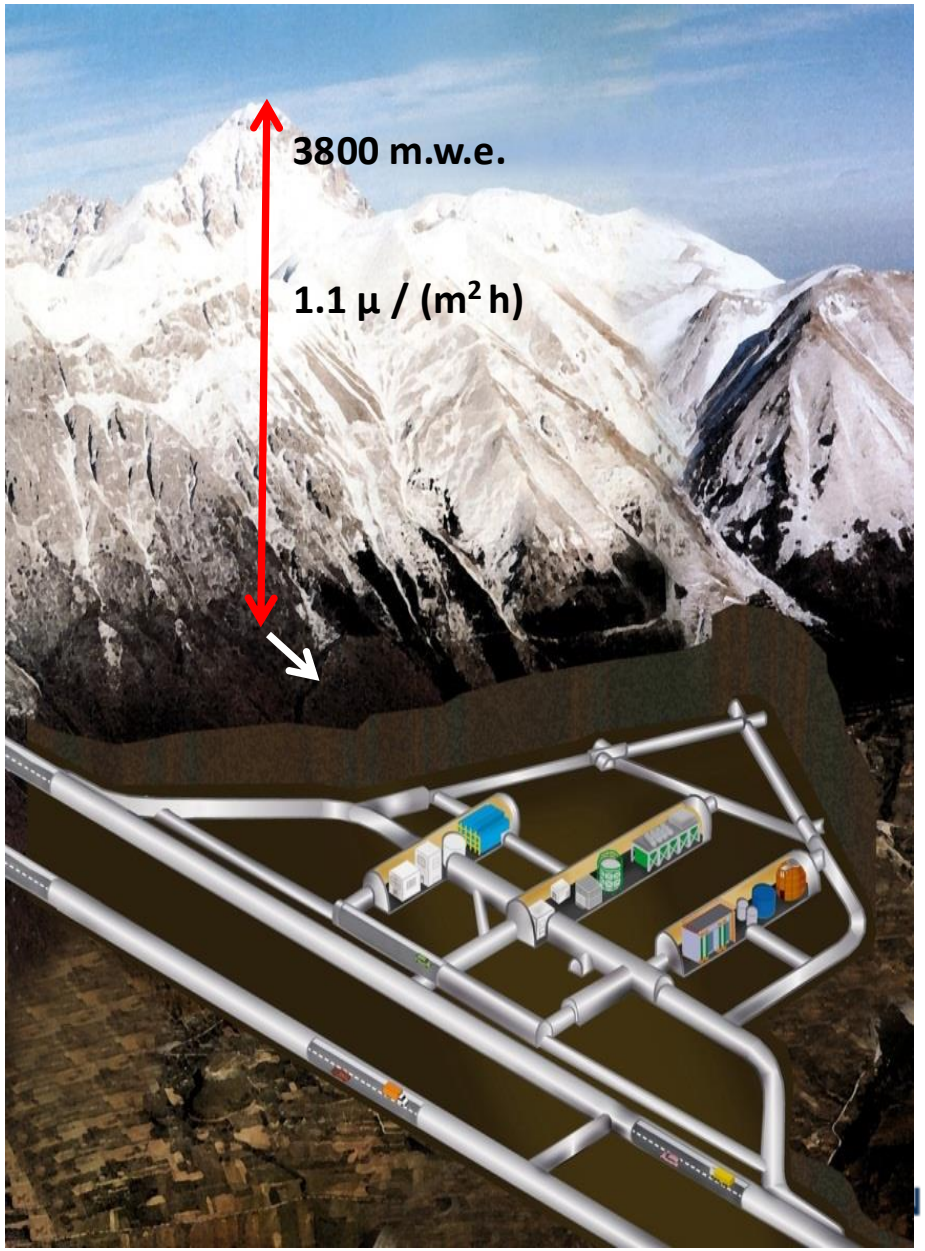
Gran Sasso National Laboratory - LNGS

Italy. Under Gran Sasso Mountains (<2hr frm Rome)
Shielded by 1400 m (3800 m.w.e.) of rock
Total Muon flux 3 10^{-8} cm^{-2} s^{-1}
Radon ~100 Bq/m3 with 5-8 air changes/day
Largest lab in Europe
3 main experimental halls:
~100 m long, 20 m width and 18 m height
Established 1980s

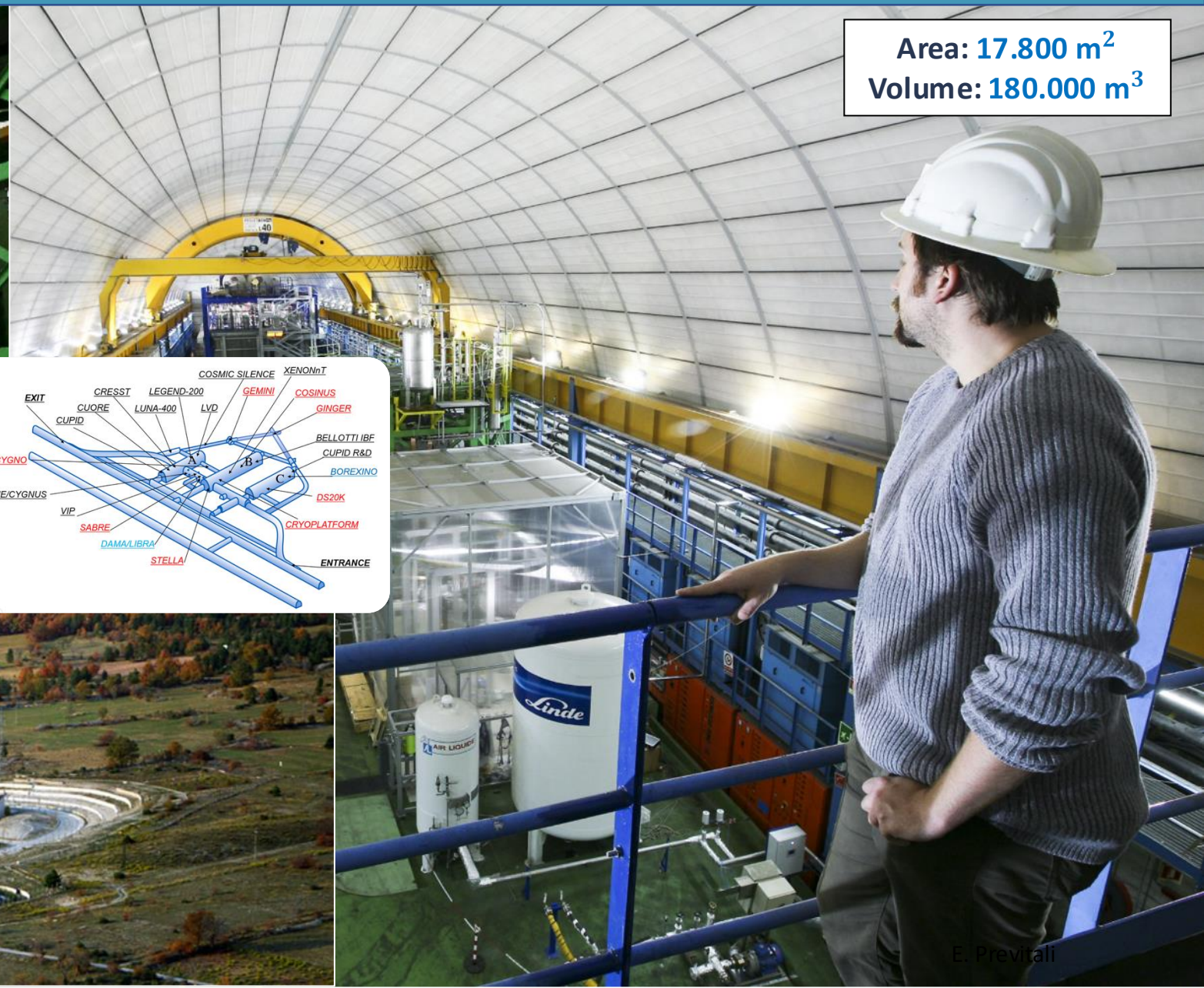
Area: 17.800 m^2
Volume: 180.000 m^3



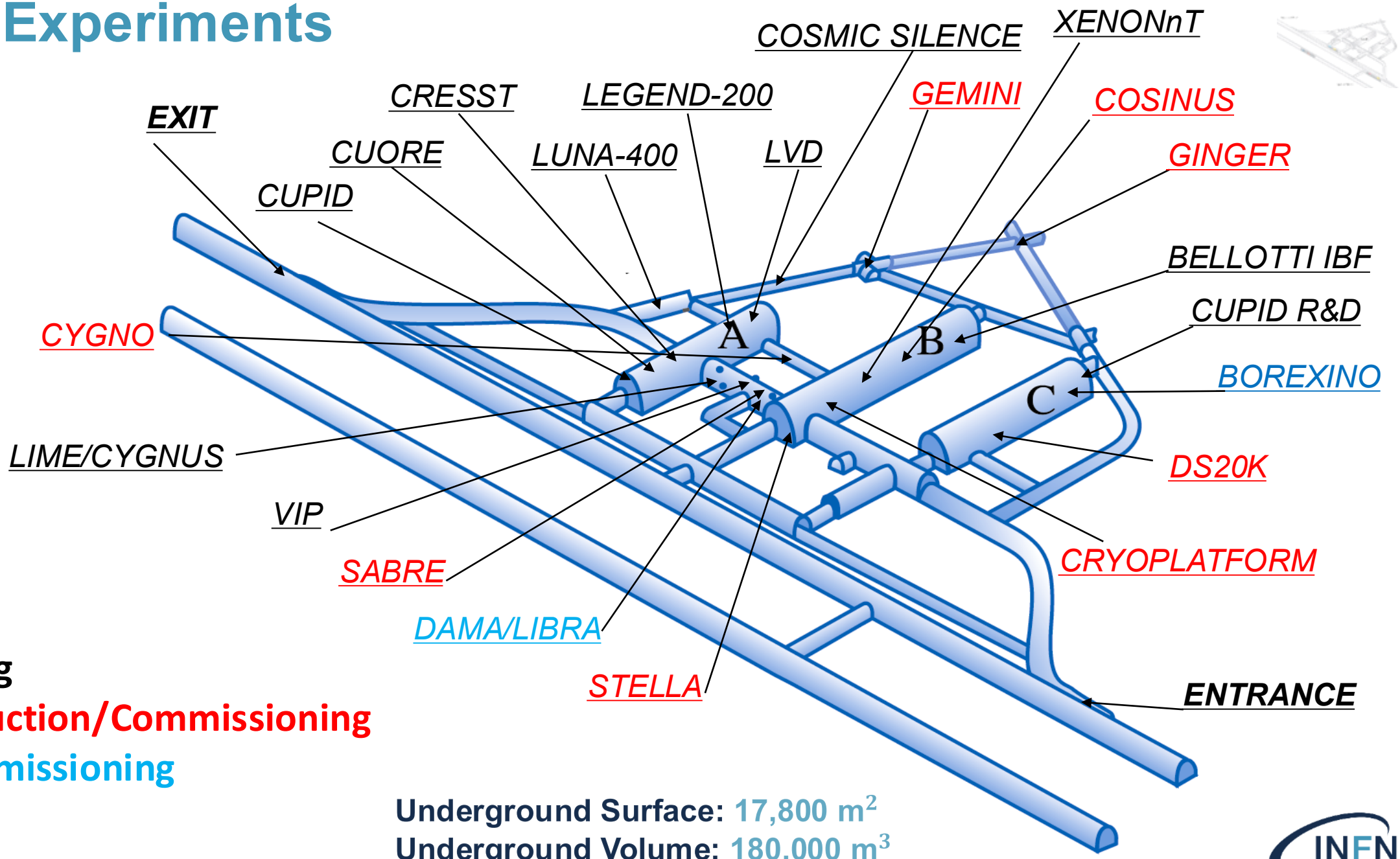




Gran Sasso National Laboratory - LNGS



LNGS Experiments



- Running
- Construction/Commissioning
- Decommissioning

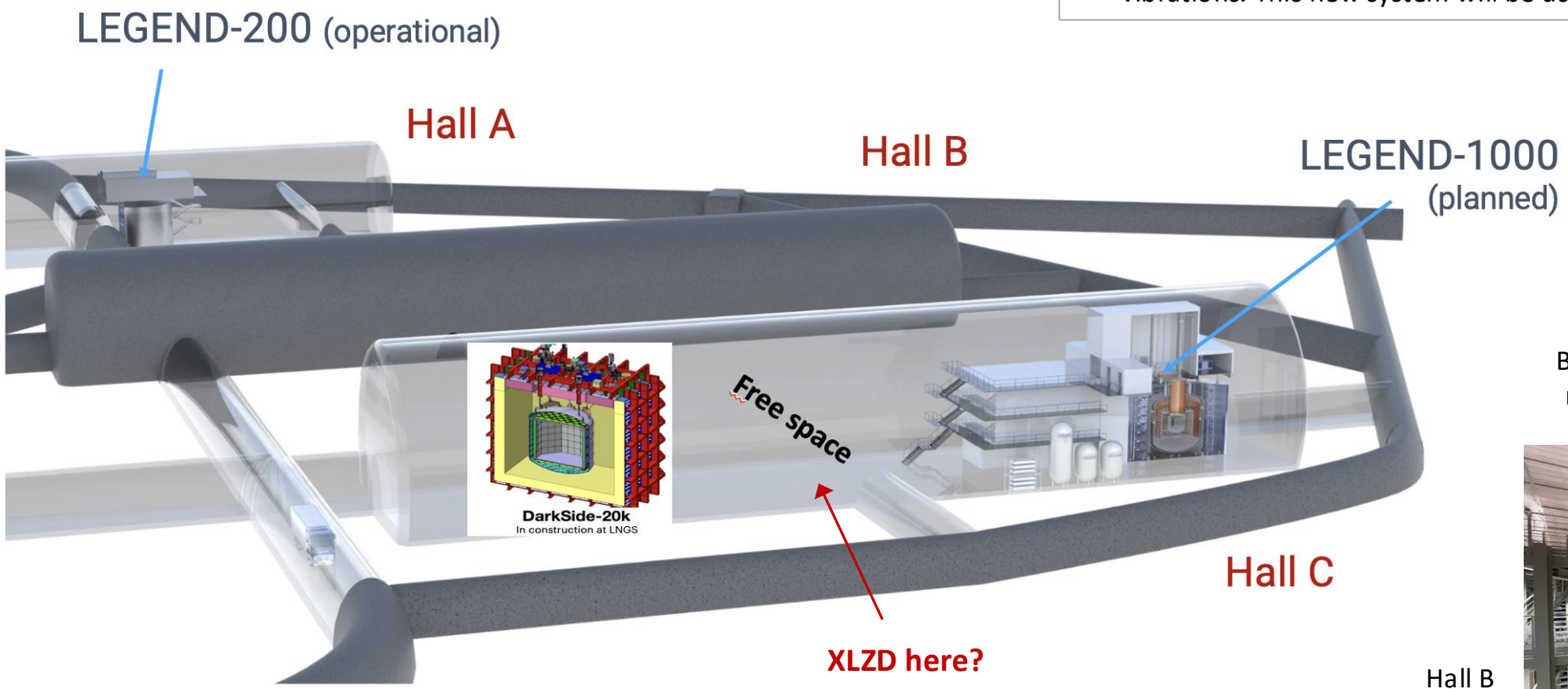
Underground Surface: 17,800 m^2
Underground Volume: 180,000 m^3

Decommissioning of Borexino and re-arrangement of LNGS Hall C

LNGS Latest News

(A. Ianni 2026)

- Decommissioning of BOREXINO started and planned to be completed in June 2027
- 2. Cryoplatform installation in Hall B in advanced stage. It will handle two cryostats for testing new technologies and physics runs
- 3. CUORE experiment reached its goal of 3 ton x year exposure. In 2027 there will be an upgrade of the cryogenic system to reduce vibrations. This new system will be used by CUPID



Hall C
Borexino
removal

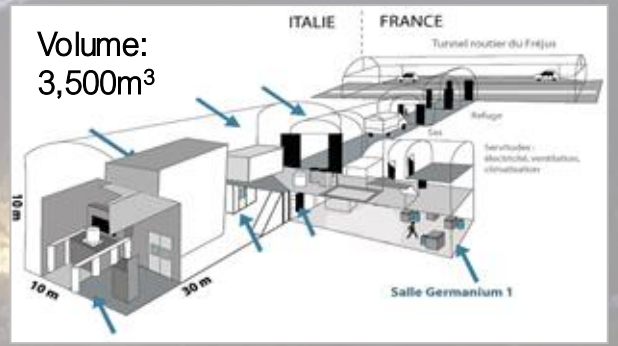
Hall B
New Cryoplatform
June 2026

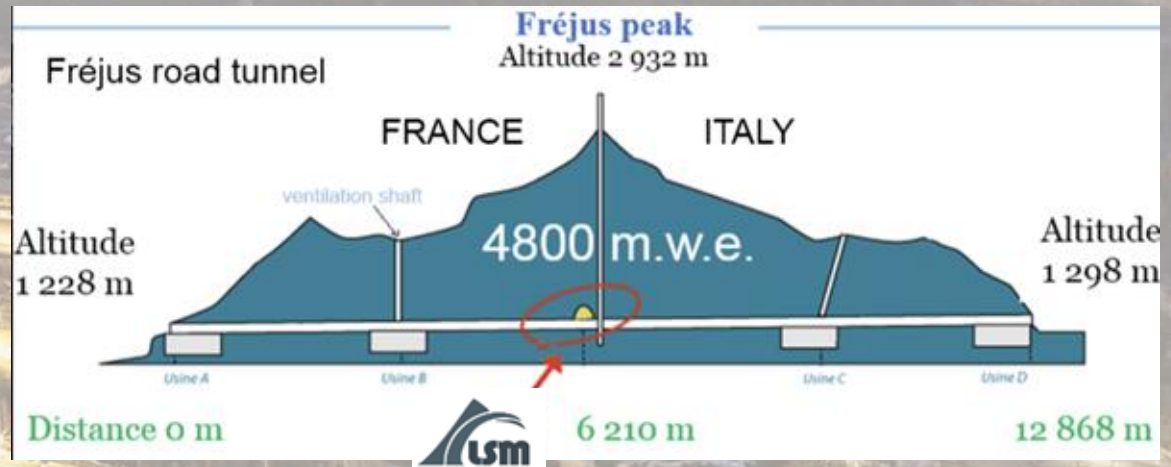
The LSM Underground Laboratory

The LSM is a French National Research Infrastructure

- Experimental site midway in the 13km France/Italy highway road tunnel
- Surface lab (*office, garage, small museum)*

- Deepest site in Europe dedicated to astroparticle, nuclear & particle physics
- 4800 m.w.e: muon flux reduced by $>10^6$ relative to surface
- Flexible access (hall accessible to trucks up to 9m);
- Natural radioactivity due to radon of about 10-15 Bq/m^3





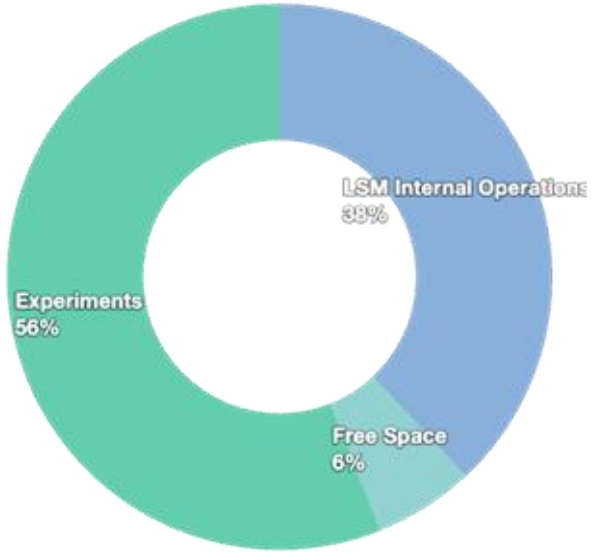
LSM Science Programme

Experiment	Domain	Technology	Description / Status
SuperNEMO	0νββ	Tracking/ calorimetry	0νββ demonstrator targeting $T_{1/2} > 6\times10^{24}$ yr (^{22}Se); first physics results expected 2026–2027
BINGO	0νββ R&D	Cryogenic	Demonstrator targeting background index of 10^{-5} counts/(keV·kg·yr). Clean room (ISO 4) commissioned.
TESSERACT	Light dark matter	Cryogenic bolometers	Expected 2028–2031; targets Ge, LHe, Al_2O_3, GaAs absorbers
DAMIC-M	Light dark matter	Silicon CCD	On-going commissioning for data taking end of 2026; ongoing R&D with LBC Module (since 2022)
MIMAC	Dark matter	Directional TPC	Innovative prototype with pixelated readout for directional dark matter detection
Obelix	82-Se/ new sample ECEC2	Ge ionisation	Countied 6 kg enriched 82-Se for ECEC2 to excited states; stopped Feb 2026.
PARTAGe	Low background	HPGe spectroscopy	National / European platform for material radiopurity screening
RAMURE / CELL TEREO/ AQURA	Life sciences & metrology	Various	Radiation impact on biology, cell cryopreservation, quantum clocks

Science programme adapted to LSM size:

- Low-mass Dark Matter Experiments
- 0vBB demonstrators & technologies
- HPGe array for low-radioactivity

Tight occupation of the available 640m^2



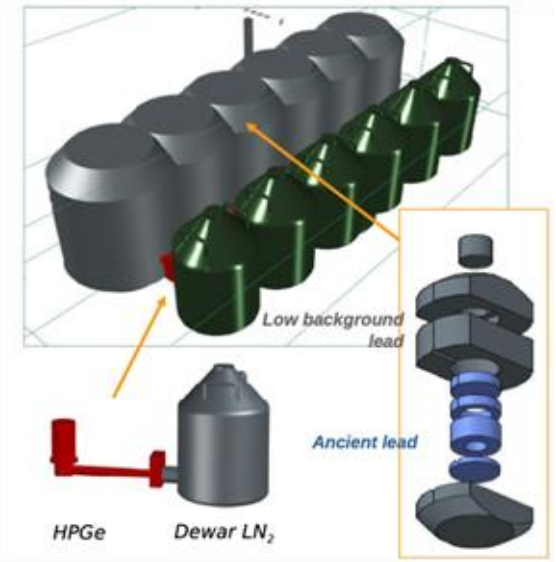
Perspective 2027:
PRISME-LSM (*Projet de Renforcement des Infrastructures Scientifiques de ModanE*) project funded.
Seven phases under analysis for optimization of laboratory volumes (mezzanines, storage)

Lab Space Optimisation Underway

Screening and Assay Facilities: PARTAGe

Footprint optimization for HPGe screening detectors

Evaporation of dewar 2.3 L/day
leading to 1.1L/min of N2 Gas



25 detectors in hands at LSM
15 installed in PARTAGe
5 detectors belonging to LSM

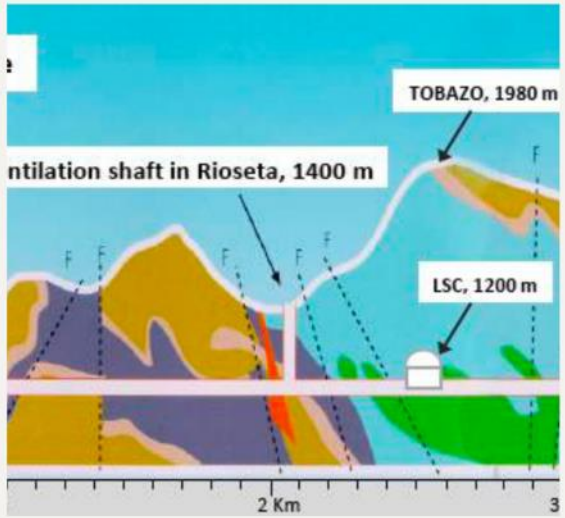
Canfranc Underground Lab

Canfranc Underground Laboratory, SPAIN
Depth = 800m
Volume = 10,000m^3

Located in Spanish-French Pyrenees border. Two-way access tunnels: abandoned train tunnel and operative road tunnel. First experiments (IGEX, …) since 1986. Modern lab, 1600 m^2, operative since 2010. 260 scientists from 50 institutions.

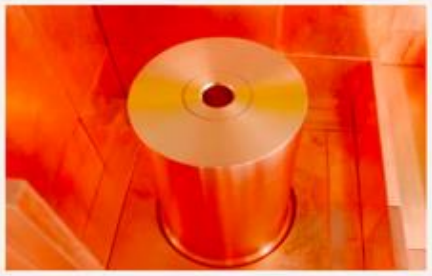
800 meters (v) of rock - muon flux is 5x10^{-7} cm^{-2}s^{-1} ; neutron flux (E<10MeV) is 3.5x10^{-6} cm^{-2}s^{-1} ; gamma flux is 2 cm^{-2}s^{-1}

Radon abatement system: 220 m^3/h radon-reduced air at 1mBq/m^3



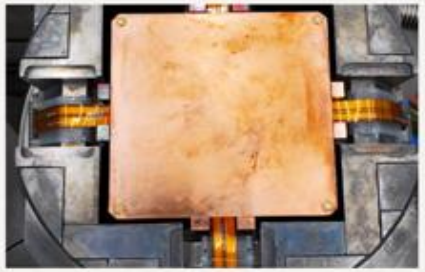
NEXT-100 experiment -TPC with 100 kg of Xe-136 at high pressure - installed @LSC to search for neutrinoless double beta decay. In operation since December 2023.

NEXT-HD - TPC with 1 ton of Xe-136 at high pressure will start construction plans in 2025. Already working on LRT for the ton-scale experiment: higher purity copper shielding, light extraction with fibers,…



HPGe detector GeRysy

ICPMS-QQQ underground



EFCu: DAMIC lids

ANAIS Experiment

C. Status of GeRysy family

New – high sensitivity HPGe systems

		Detection limits: [mBq] / [mBq/kg]				
		^{226}Ra	^{228}Th	^{137}Cs	^{60}Co	^{40}K
Well	Low density	0.02 1.0	0.03 1.7	0.005 0.2	0.005 0.2	0.15 7.3
	High density	0.03 0.14	0.04 0.23	0.005 0.03	0.006 0.03	0.18 1.0
Detector chamber	Low density	0.3 0.02	0.5 0.03	0.08 0.005	0.08 0.005	2.4 0.16
	High density	1.4 0.01	2.4 0.02	0.3 0.002	0.2 0.002	5.1 0.04

Table 3: Detection limits for absolute activities (first number in the row) and specific activities (second number in the row) of low (1 g/cm^3) and high density (9 g/cm^3) samples placed in the detector well (20 cm^3 volume) or in the chamber (15 L volume).

GeRysy-1 screening: stainless steel (LEGEND, DS-20k), ULTEM insulator (LEGEND), WLS Fibers (LEGEND), 3D Printed Dental Resin Sample (LEGEND), Ph-Br (LEGEND), ESR Film (DS-20k) SMD Resistors (DS-20k), TX-100 Liquid Scintillator (DS-20k), Optical Gel (NEXT-100), Peek screws (NEXT-100), Teflon screws (NEXT-100).

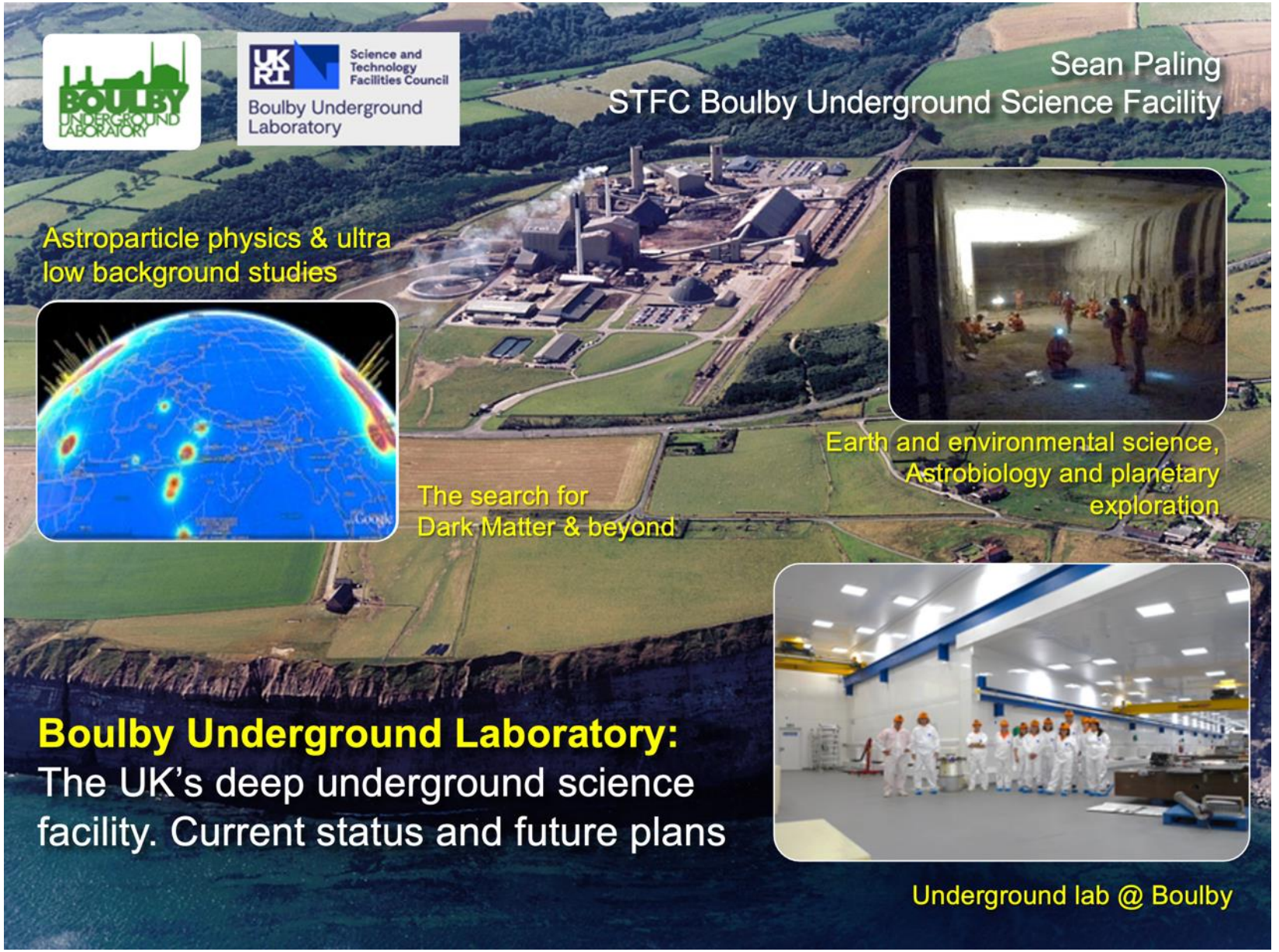
Gerysy-2: arrived at LSC. Copper blocks produced by the KGHM Polska Miedź Company (from fresh and selected cathodes) in 2025. Cast Cu blocks (100 cm x 100 cm x 20 cm) hot-forged, cut into smaller blocks (20 cm x 20 cm x 800 cm) and stored underground (1.3 ppt U, 0.2 ppt Th). Gamma counting is in preparation, ^{210}Pb determination is ongoing. Cu for fabrication of detector cryostat delivered to Canberra/Mirion. Machining of shield parts ongoing in Kraków.

Gerysy-3: Copper electroforming elements in preparation for GeRysy-3.

Science and Technology Facilities Council

Boulby Underground Laboratory: Status and plans for the UK's deep underground science facility.

See talk by Beth Green - At this conference.



Sean Paling. Boulby Underground Lab. 2026

Science Programme Status and Plans.

- Low background Particle and Nuclear Physics
- Earth & Environmental Science
- Astrobiology & Planetary Exploration Studies
- Quantum Sensors and Computing (new)
- Outreach & Education

See Boulby Lab talk by Beth Green

Supported access to surrounding geology & UG environs. Power, wifi/internet.

3000m^3 Outside Experimentation Area

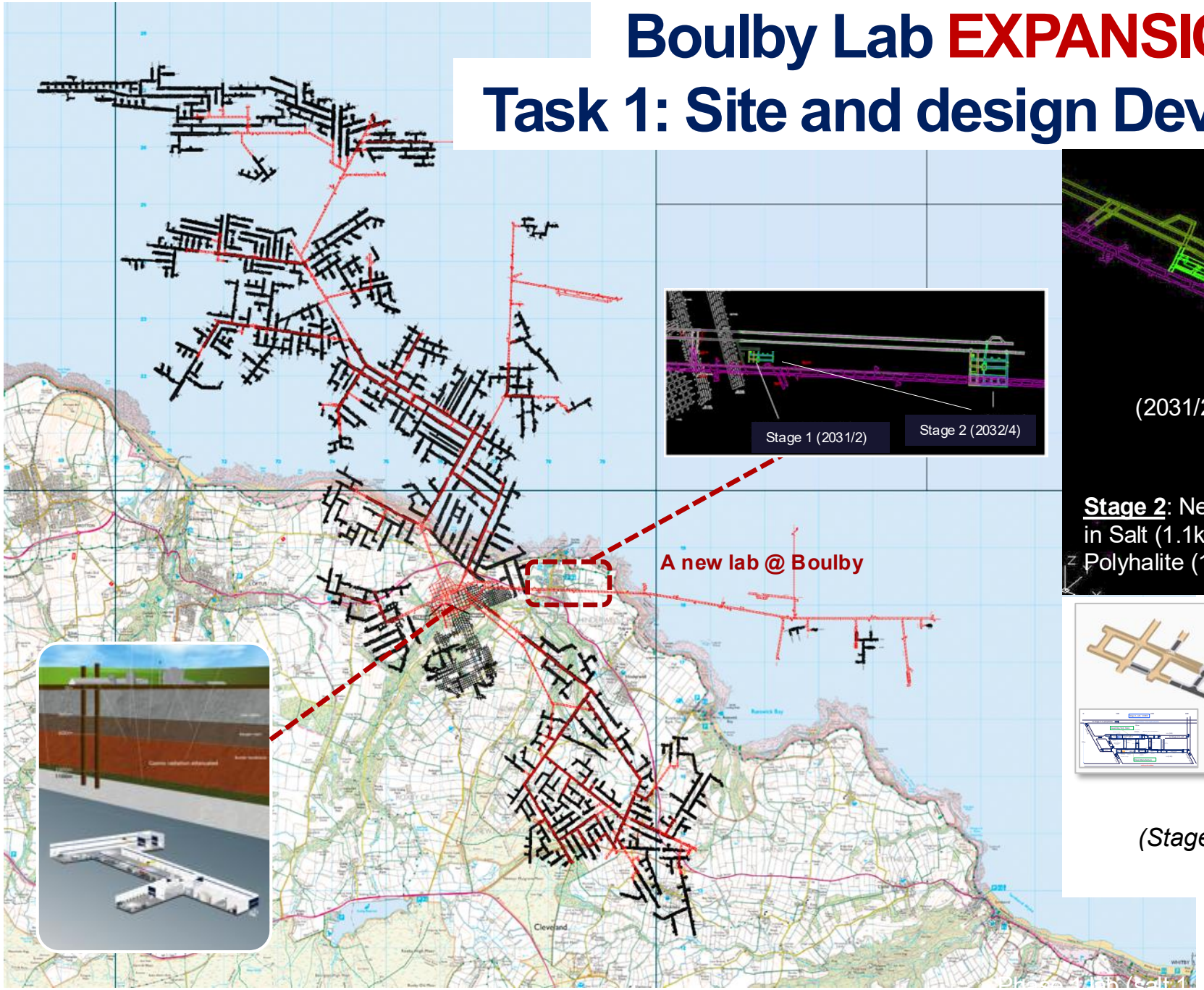
Volume 4000m^3
Depth 1,100m
(>2800 m.w.e.)
Radon <3Bq/m^3

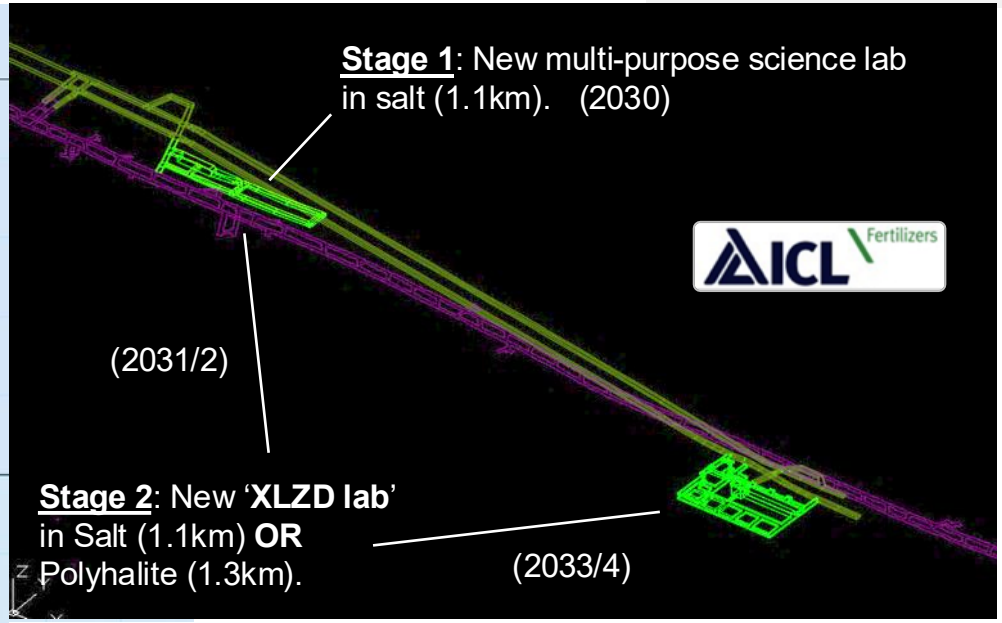
BUGS Material screening

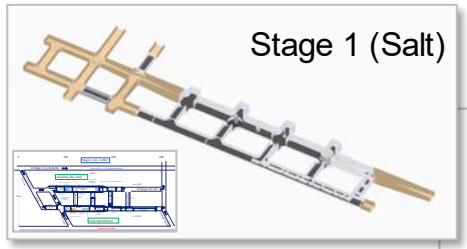
Boulby Underground Lab Facilities 2024: >4000m^3 class 1k & 10k (ISO 6 & 7) clean room lab space. 10Gb Internet. AC, air filtration, 5T & 10T lifting, LN generation, fume hood & clean prep space. 3000m^3 Outside Experimentation Area (OEA) with power & internet. Supported access to wider mine environs.

Boulby Lab EXPANSION Project
Task 1: Site and design Development.

Science and Technology Facilities Council
Boulby Underground Laboratory

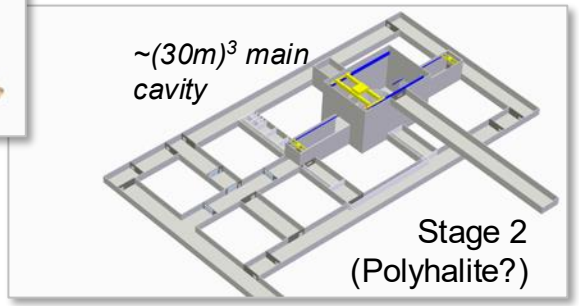






Total volume (Stage 1 + stage 2) ~120,000m³

DRAFT: 2-stage design



Excavations for stage 1 of expansion by ICL-UK began in mid-2024.

Stage 1: A new world-class multi-disciplinary deep underground science facility.

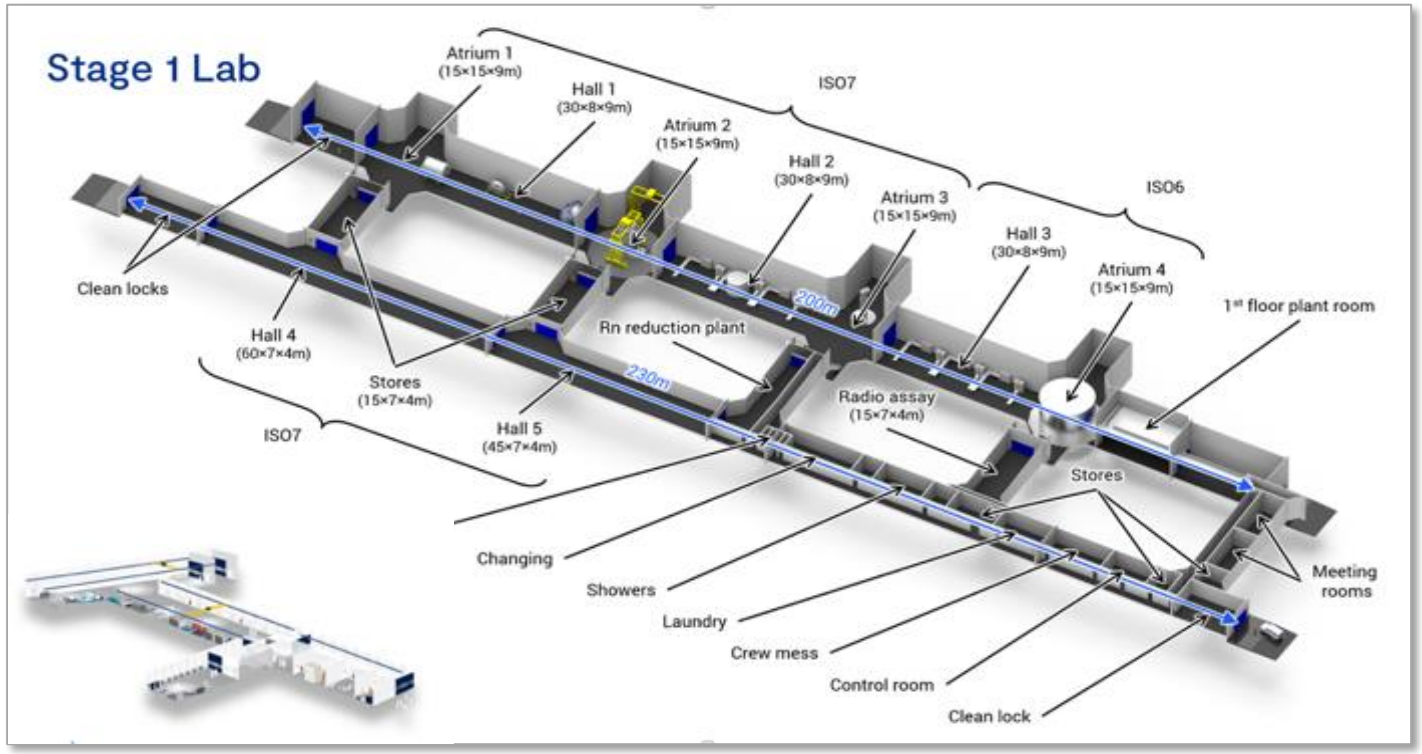


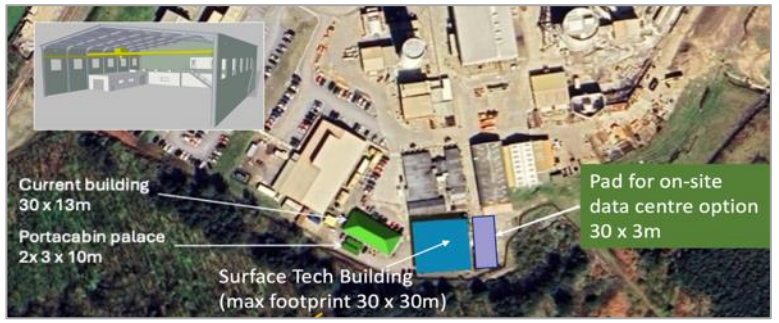
Image Credit: A Ball, J Elmer, C Kinahan, J Hill et al.

EXCAVATION NOW COMPLETE

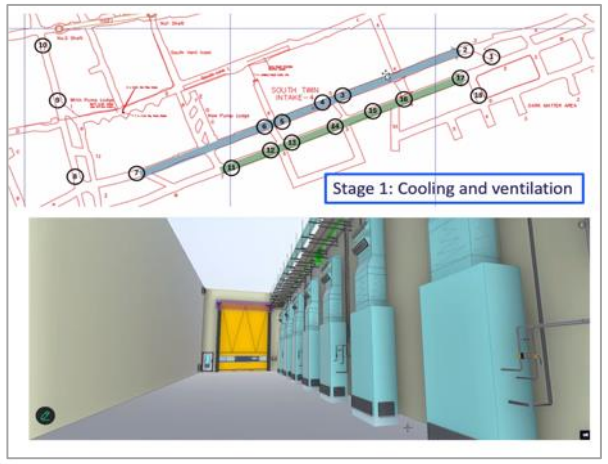
Planning for laboratory outfitting now underway

Stage 1 Outfitting

A new, world-class multidisciplinary science facility, complementing and succeeding the current Boulby laboratory



Surface Building Development

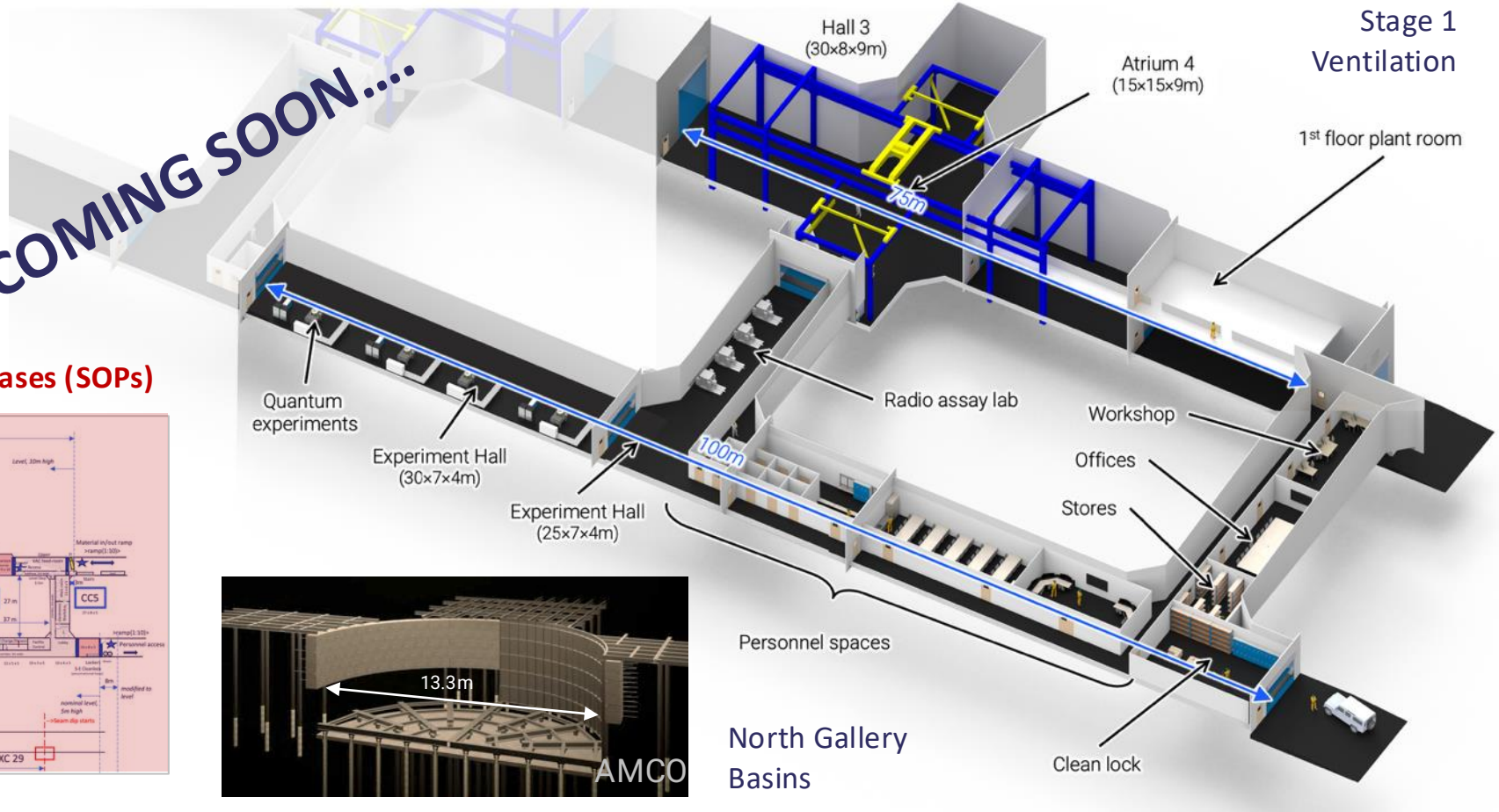


Stage 1 Lining Options

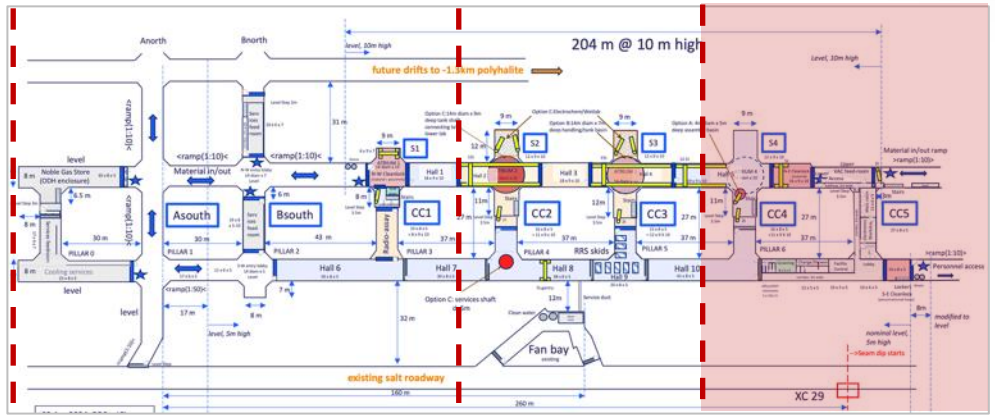
Possibility for single shot or staged outfitting

COMING SOON....

Stage 1 Ventilation



Staged outfitting phases (SOPs)



SOP3 SOP2 SOP1

North Gallery Basins

Plans for XLZD@Boulby

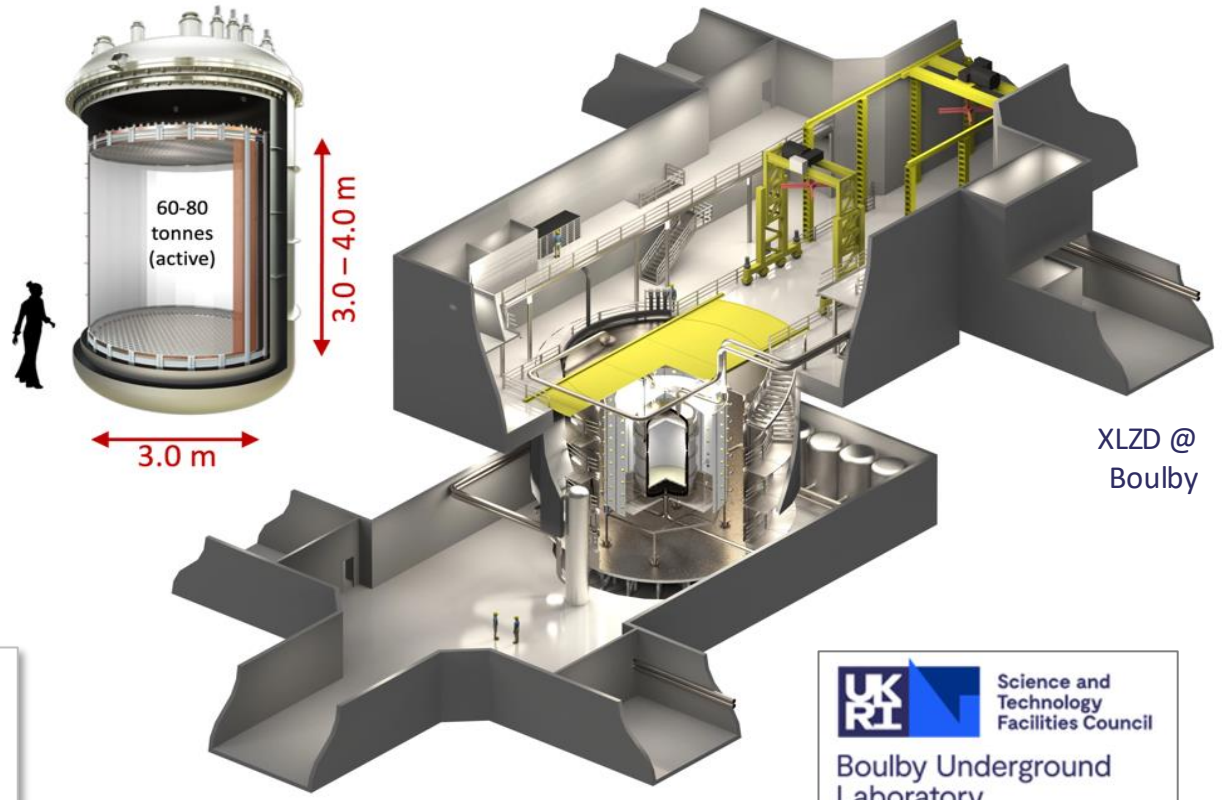
The international XLZD collaboration are looking at 4 potential Underground Labs to host the project:

- SURF (USA)
- SNOLAB (Canada)
- LNGS (Italy)
- **Boulby (UK)**

Host site decision
2026/7?

Boulby Offers

- A tailored-made laboratory!
- Excellent & proven UK science expertise and capability.
- Good / accessible location
- Strong Local / National support



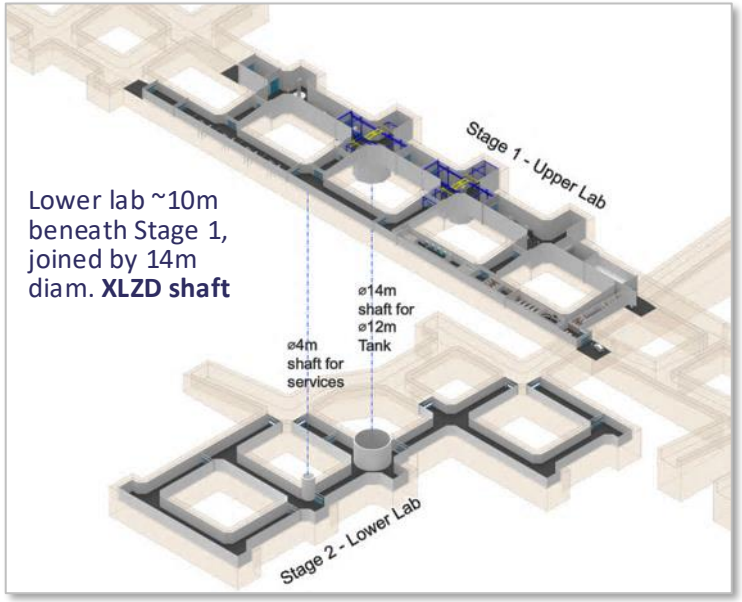
XLZD @ Boulby

Science and Technology Facilities Council
Boulby Underground Laboratory

Ongoing design & planning efforts for the XLZD Dark Matter & Rare-Event detector coming to Boulby

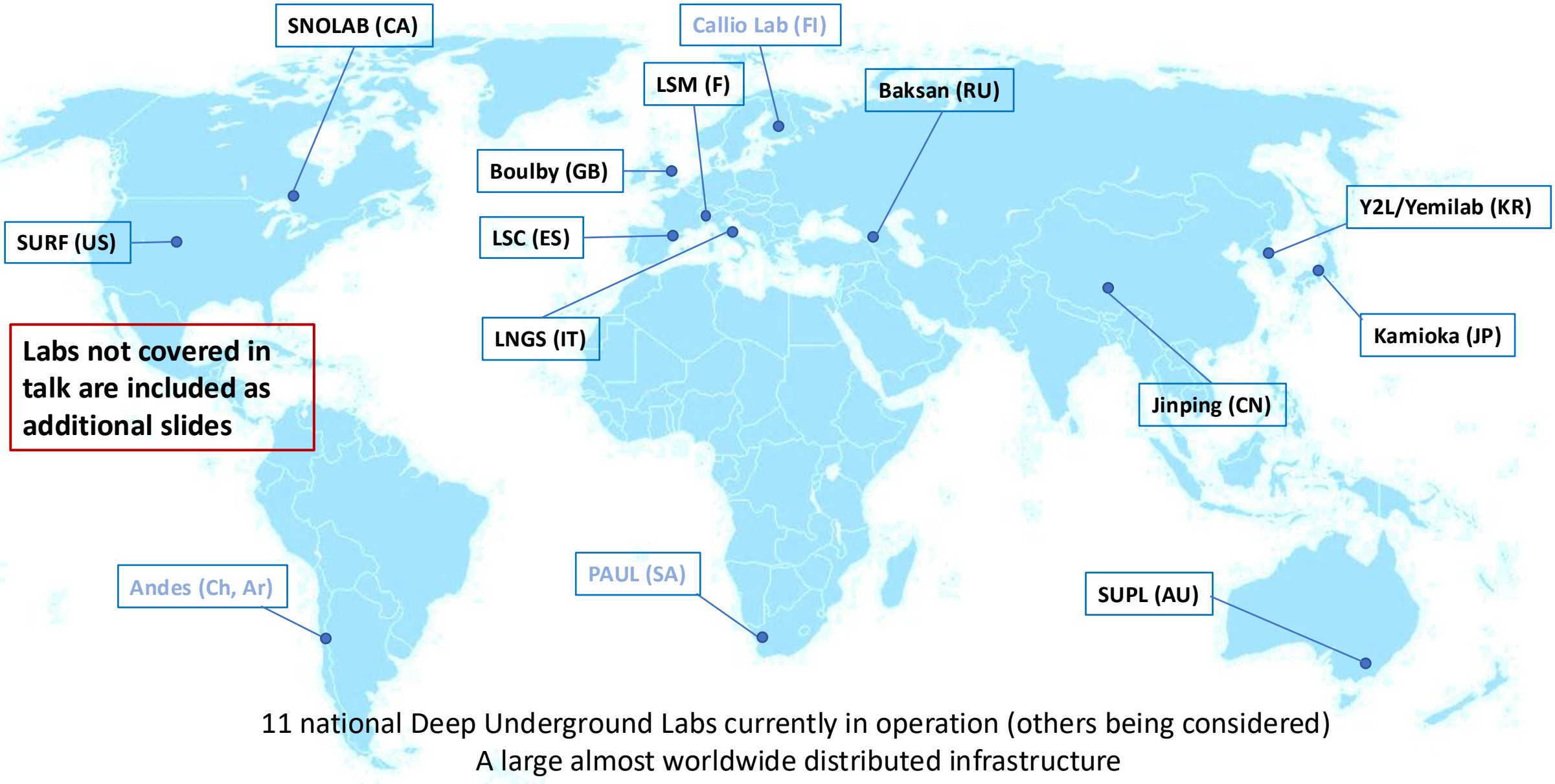
Latest news from XLZD-UK:

- New simulations show 1.1km depth is fine for XLZD science ambitions
- **Stage 2 in SALT is now Boulby Plan A.**
- QUICKER and CHEAPER to deliver and operate
- Lab(s) in the Polyhalite layer are also still an option.



Stage 2 & Stage 1 in Salt

World Deep Underground Science Labs



Labs not covered in talk are included as additional slides

11 national Deep Underground Labs currently in operation (others being considered)
A large almost worldwide distributed infrastructure

Overview of World Deep Underground Science Facilities - SUMMARY

Globally there is wide variety of excellent deep underground science facilities operating. (I believe) the underground science communities are well served by the facilities that have emerged to meet their various needs.

In the future:

- Science projects (and demands on facilities) will grow:
- Some large spaces needed, more stringent cleanliness and low background requirements, more severe engineering and technology challenges, and more.
- The underground labs will be (and are) looking to meet these needs.

International Underground Lab cooperation.

- Benefit to be had from sharing of operational practices and possibly international coordination of use of space and support systems (low background counting etc)…

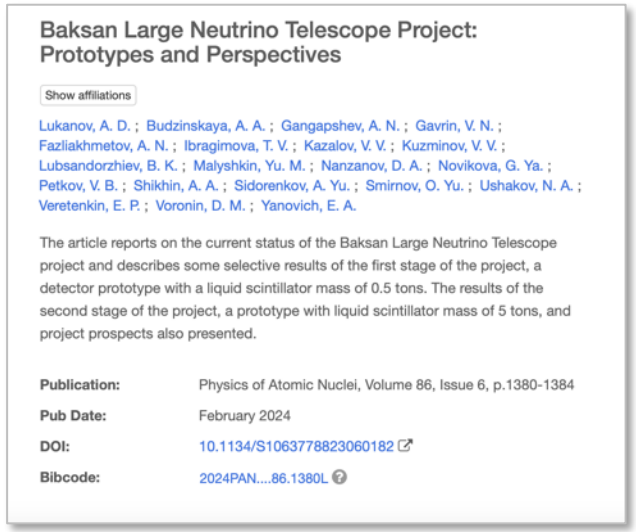
'NEXUS' proposal funded
'EULIP' proposal submitted

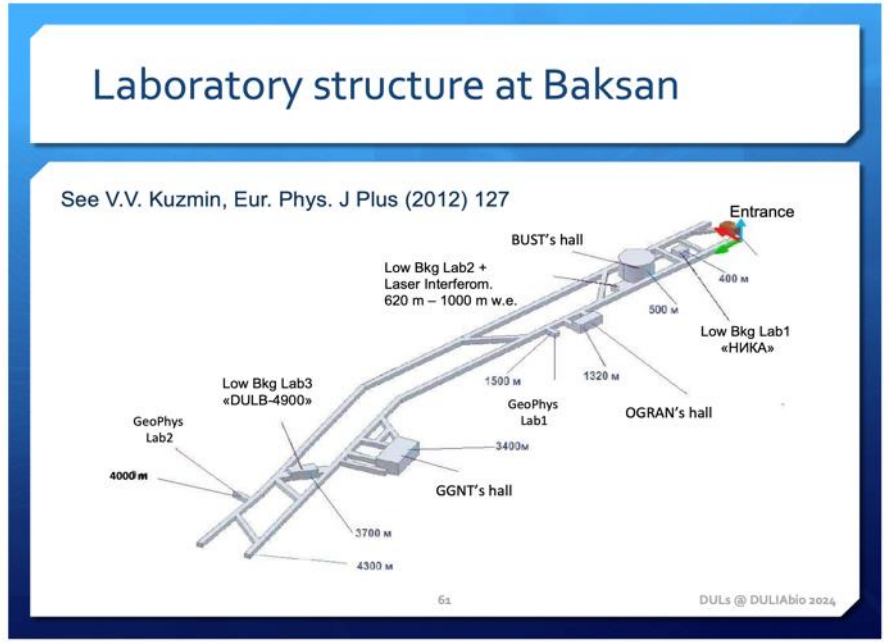
Sean Paling
STFC Boulby Underground Laboratory

Science and Technology Facilities Council
Boulby Underground Laboratory

Additional Slides

BAKSAN Neutrino Observatory (Russia)

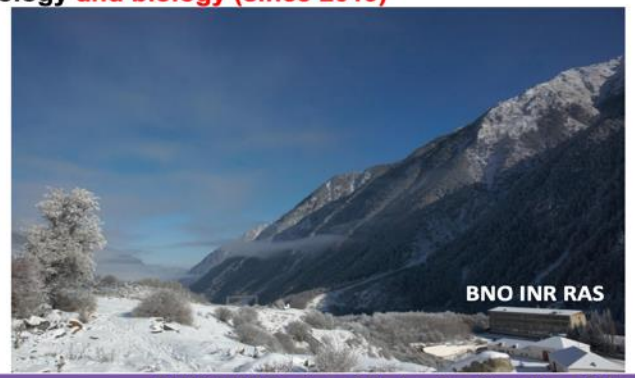




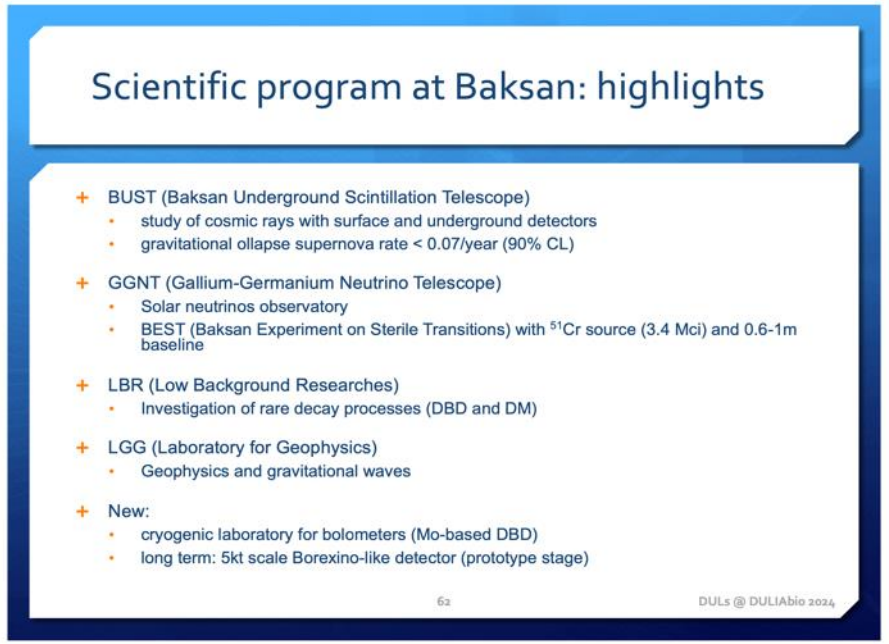
https://indico.stfc.ac.uk/event/1058/

Baksan Neutrino Observatory

BNO (INR RAS) was founded in the late 60-80th in the Neutrino Village (1700 m.a.s.l.) located 22 km from the highest european mountain Elbrus (5642 m, dormant volcano) under the peak of Andyrchy mountain (3937 m). Main scientific goals of BNO are related to fields of astrophysics, particle physics and nuclear physics. Moreover newer topics of interdisciplinary research are linked to geophysics, geology and biology (since 2019)



DLNP JINR Sector of Molecular Genetics of the Cell



Misc Sources…

Engineering Design ANDES

The ANDES Laboratory project design is ready to be included in the Agua Negra tunnel call for tenders

Towards a new lab in South America?

Agua Negra tunnel **(1)**

Located 1700m underneath the Andes mountains between Chile and Argentina. There is a new initative to activativate the Agua Negra tunnel construction

Andeslab.org

Alberto Etchegoyen –
alberto.etchegoyen@iteda.gob.ar
Manuel Platino –
manuel.platino@iteda.gob.ar

Argentina and Chile collaborators designed, built, and tested two innovative (3-x/y planes) muon veto telescopes ready to be installed (see poster 517)

Advanced research in MMCs and digital SiPMs in conjunction between ITeDA and KIT (Germany)

Paarl Africa Underground Laboratory

Symposium on Science at PAUL

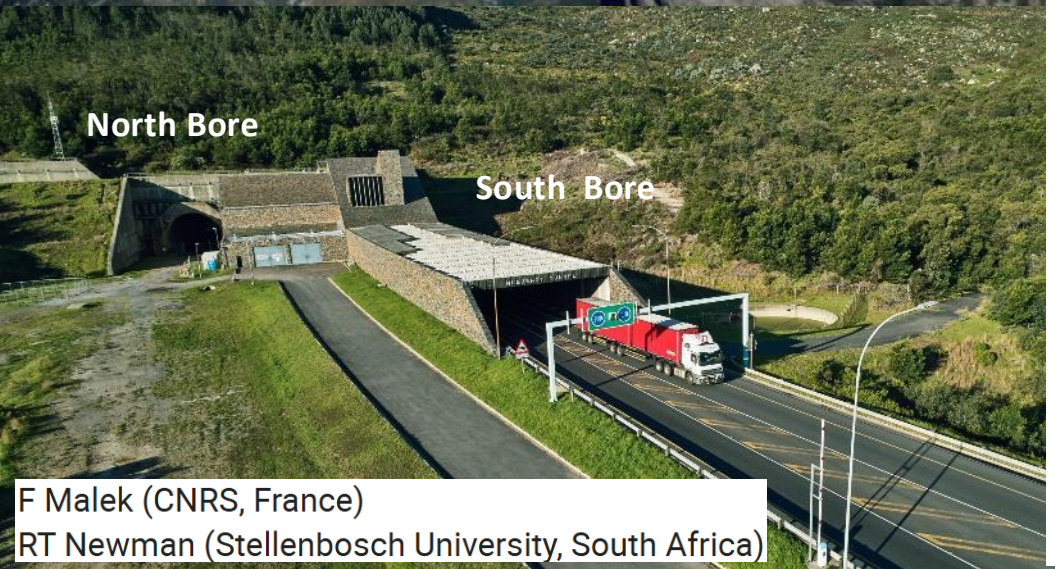
14–18 Jan 2024
Du Kloof Lodge, Du Toitskloof Mountains
Africa/Johannesburg timezone

Du Toitskloof Tunnel

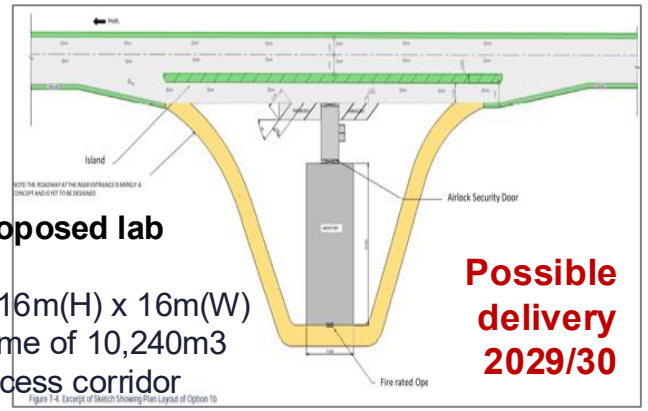
Du Toits Kloof tunnel view point

Manganese Mine

Plans for a new lab in South Africa



F Malek (CNRS, France)
RT Newman (Stellenbosch University, South Africa)



One of 3 proposed lab designs. ~

- 40m(L) x 16m(H) x 16m(W)
- Total volume of 10,240m3 inc an access corridor

Possible delivery 2029/30

Muography of tunnel: 1,5 years of measurements in- and outside of tunnel

Muon tracker from J.Marteau (IP2I Lyon, FR)

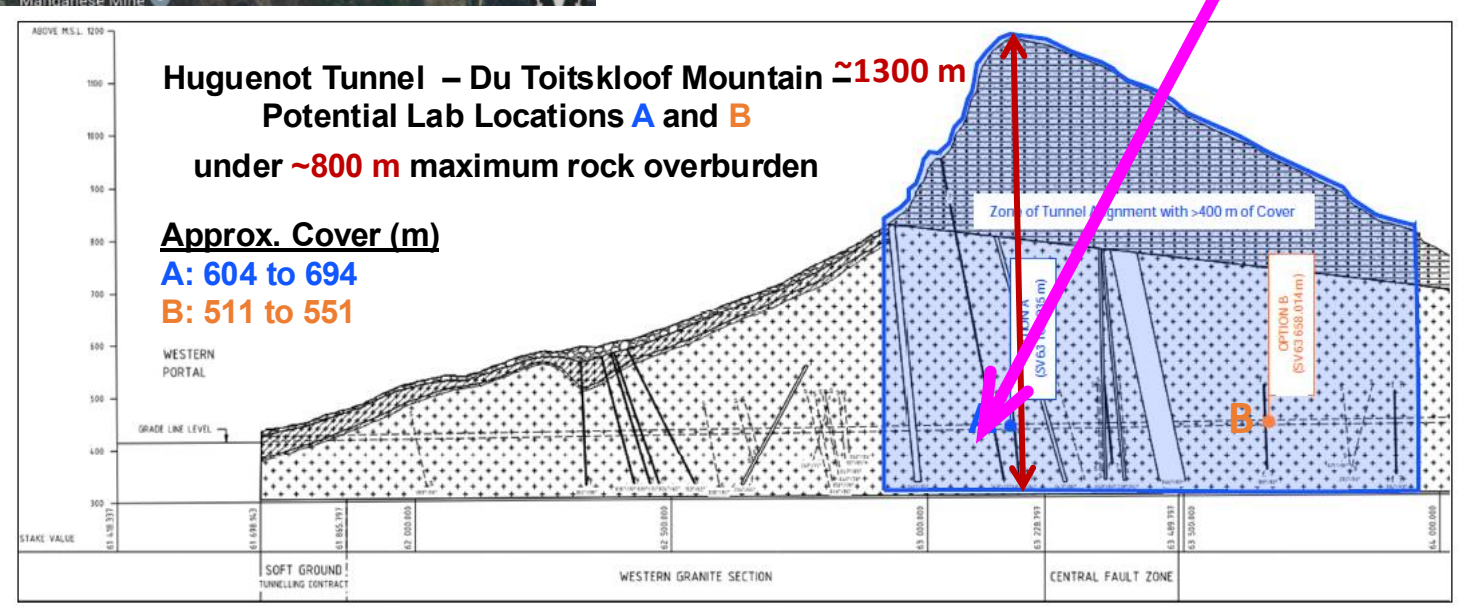


Figure 6-1. Proposed PAUL locations are shown on an excerpt of the geological longitudinal section (drawing no. C1870-0300-DRG-STN-233011)